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TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF

IRELAND.

Vol. IX.

DUBLIN:
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TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF IRELAND.

[Read January 10th, 1866.]

On the RATHMINES WATERWORKS.—By HENRY JOHNSTON, Member.

BEFORE entering upon the details of the Waterworks constructed under my superintendence for the Township of Rathmines and Rathgar, a short review of the circumstances which led to the construction of these works, in their present form, is necessary for a clear explanation of some points in connexion with them.

The Township was incorporated in the year 1847. In the programme of the promoters, although a supply of water was contemplated, it was distinctly stated that—" with respect to a supply of water, although powers will be taken in regard to it, it is not expected or contemplated, for some time at least, that the Commissioners will have it in their power, from various circumstances, to undertake anything in respect to this important point." The powers taken by that Act were very full, and proved ample for all purposes connected with water supply; for instance, the 13th clause gives power of a very unusual character, the Commissioners being authorized by it to break up "any road, street, or place, within or *outside* the said district," to lay mains, &c.; a very comprehensive power indeed. It should be mentioned that previous

to this time (in 1845), the Corporation had obtained power, under certain restrictions, to supply water to a district, of which Rathmines formed part, but the relative levels of the existing works and the Rathmines Township rendered it impossible to do so.

In 1861, when the Vartry scheme was brought before Parliament, powers were sought for by the Corporation to enter the Rathmines district as a water company. This was strongly but unsuccessfully resisted by my Board; and the Chairman, Mr. Stokes, who had conducted the opposition in London, being impressed with the necessity, from the course the contest had taken, of providing independent works, on his return, in conjunction with his colleagues, made arrangements with the Grand Canal Company for a supply of water, on very advantageous terms, involving a very trifling annual payment, they (the Canal Company) being naturally desirous of showing that the water was not of the foul and impure character it was represented to be. More than 1,000 houses have already been supplied with it for domestic purposes, and not a single complaint has ever been made as to either its quantity or quality. It is taken from a source upwards of 100 feet above the level of the City basin at Portobello, and the supply regulated by means of an overfall, four inches below any other outlet on the same level, which is more than a mile in length; consequently a preferential and unfailing supply is secured.

In some respects the plan adopted resembles one of the two put forward by Mr. Mallet in his evidence for the promoters of the Rathmines Improvement Bill, but is taken from a higher level. Mr. Mallet contemplated only going to the 6th lock, while the present supply is taken above the 8th lock; and there was no filtration provided in the plans then submitted. While Mr. Mallet allowed six gallons per head for a population of 12,000, our works are sufficient to give a

supply of forty gallons per head to double our present population, which is twice the quantity necessary where there are no manufactories.

The Commissioners appointed a Water Committee from amongst their members (Messrs. Stokes, the Chairman; Parker, and Drury), and to them was entrusted the carrying out of all the official and practical details of the scheme. Those gentlemen, determined upon having the most perfect arrangement for collecting, filtering, storing, and distributing the water to every part of the Township, directed me to consult Mr. Bateman, of London, on the subject, admittedly the first Water Engineer of the day, and having received from him designs of the most approved method of so doing, the formation of the works was commenced in September, 1862, and in ten months from that time the water flowed through the principal roads of the Township. I may here mention that the Water Committee, with great judgment and forethought, took advantage of the favourable state of the iron market, without waiting until the plans for the works were fully matured, and entered into a contract for the entire quantity of water mains at a very low price, with Messrs. Robert M'Laren and Co., Eglinton Foundry, Glasgow, after having received proposals for the work from several English, Scotch, and Irish houses in the trade. It is computed that a saving to the Township of at least £2,000 was effected by the arrangement, as the price of pipes advanced considerably soon afterwards.

A suitable position for the works not being procurable on the Southern, or Rathmines side of the Canal, a convenient site was obtained for the purpose on the Northern side, at Gallanstown, above the 8th lock, and about 4½ miles from the Township, a position where the level, as already mentioned, is more than a mile in length, and, consequently, forms an immense reservoir of water, still, therefore, clear 178 feet

above the Ordnance datum. It thus became necessary to conduct the filtered water from the reservoir to the Township, through a 15-inch diameter pipe, laid across the Canal, eight feet under the top of water line. This pipe has flanged joints, bolted together on gutta percha washers; and to lay it a coffer dam had to be constructed, in the first instance, half-way across the Canal, so as not to interfere with the traffic of boats. One-half the length of the pipe was laid, the dam then removed, and reconstructed in a similar manner to lay the remaining portion of the pipe.

The width of the dam between the piling was three feet six inches, filled with strong clay puddle. The piles were composed of timber, 7 inches wide by 3 inches thick, driven firmly into the bed of Canal. There were two rows of waling on each side, 12 inches by 4 inches, the lower row angle braced from the Canal banks, the upper ones having one inch diameter wrought-iron tie rods above the level of the water. The dams were drained without pumping, by means of cuts through the towing paths, down to the level of Canal bottom, and discharging into the waste water drain or ditch at each side. Before laying the 15-inch pipe, piles and stone blockings were introduced in the bed, to prevent the possibility of its deflection or disturbance. When laying this pipe, the end of it at the centre of the Canal was projected about 6 inches into the puddle through the inner piling of the end of dam. This process saved a great deal of time and expense, as only one side of the end of dam had to be constructed. That part which formed the inside of first half suited for the outside of second portion, and left the flanged end of pipe clear for connexion.

Although the providing and laying the pipe, and constructing the coffer-dam, involved a large outlay, the formation of the works on the Southern side would have been much more costly, and by no means so permanent or satisfactory, on account of the high embankments (and consequent risk) which

it would have been necessary to form round the reservoir and filtered beds, the land being several feet below the level of that on the opposite side, where the works have been made.

There are three filter beds, each of which is 60 feet by 40 feet, and 6 feet 6 inches deep. The water is admitted into them from the Canal through a 15-inch pipe, which is inserted in the western embankment, nearly on a level with the floor of the beds; it rises from thence though the admission wells, and spreading over the surface of the filtering material, which is composed of fine sand, gravel, and broken stones, in successive strata or layers, percolates as it filters through open work brick drains, covered with random flagging, into the outlet wells, and thence into the reservoir for distribution. In each of these admission wells is placed a valve, by which the water can be shut out from any one of the beds for the purpose of cleaning, washing, or renewing the filtering materials, the other two being quite ample for supplying the reservoir. The outlet wells have also side valves, in connexion with a 6-inch waste pipe, aid in the enbankment, which drains the filter beds, after the valve on the pipe which supplies the filter beds from the Canal, and also the valve on the pipe leading into the reservoir have been shut off. The floors and sides of beds are lined with fire bricks, set in hydraulic mortar; the admission and outlet wells are built of similar materials, and finished on top with heavy granite coping. A puddle wall, two feet thick, and extending one foot below the level of floors, is inserted in all embankments surrounding the filter beds and reservoir. The earth or foundation floor of the works is naturally a stiff retentive clay, not requiring puddle or other material to render it thoroughly water-tight. These filters prepare about half a million gallons per day, and there is sufficient land to construct double the present number of beds, should they be required, while the main pipe is more than sufficient to pass down a million gallons daily.

The reservoir is 140 feet by 70 feet, and the top water line 6 feet 6 inches on average. The floor is laid with an incline of one foot towards the distributing main, at which point there is always 7 feet of water, while at the opposite end there is but 6 feet. The floors, walls, piers, and arching are built with best English fire bricks, set in hydraulic mortar; the arches are 9 inches thick, the crowns of which are rendered water-tight by a coating of asphalte, one inch thick. A four-inch pipe, covered with broken stones, is laid between the springings of the arches, to collect and discharge the top drainage at each side into a waste pipe communicating with the boundary ditch. The whole is covered with clay and sods to an even surface, keeping the water underneath in the coolest and best order for distribution. A draught of air is caused to circulate between the top of the water and the soffits of the arches, by means of ventilating louvres, inserted in the spandril walls at both ends of each arch.

In the original plan it was proposed to lay a 12-inch main pipe from the works to the Township, but it was afterwards considered expedient to substitute a 15-inch in the first instance for a mile, but afterwards for the greater portion of the length. The result of the alteration has been to give an additional elevation of 15 to 20 feet to the water supplied to the houses situate in the highest portion of the Township at Rathgar, and to reduce the friction in the mains from 10 feet per mile to 6 feet.

Between the works and the Township there are 4 valves on this main, about equidistant one from the other, and behind each of those valves a branch with by-wash is attached, so that in the event of accident or leakage, the water can be shut off and emptied out of each section for repairs. The distributing mains in the Township vary in size from 9 inches to 3 inches, according to locality or to the population to be supplied; 3-inch service mains are laid besides all the larger

ones for tapping, and are arranged so as only to deprive a limited number of houses of water at a time, during the process of fitting for domestic purposes, which generally occupies three hours. It would prove very inconvenient to persons living at the extreme end of the Township, if, when a house quite close to the Canal were fitting for supply, their houses, as well as several hundred others along the line of main, were deprived of water for even so short a period. All the mains have been prepared with turned and bored joints, and have not only proved perfectly staunch, but also saved a very large sum of money, which would have been expended on labour and lead, if the old system of joints had been adopted. All the pipes are laid so as to have 3 feet of covering from the surface of the roads, and in no instance have the joints been acted upon by atmospheric changes. The valves used throughout the works were supplied by Messrs. Guest and Chrimes, of Rotherham; the hydrants and fountains by Leadbetter and Co., of Glasgow, all of which were of excellent workmanship, and have given the utmost satisfaction. The lead service pipes, which are unusually heavy, for the prevention of bursting by frost or excessive pressure, as well as brass work in ferules, stop-cocks, couplings, &c., for internal fittings, have been supplied by Dublin houses.

The entire outlay from first to last amounted to £16,800, made up as follows:—

2,200 tons of pipes, valves, and laying ...	£12,538	0	0
Reservoir, filter beds, boundary walls and other works at Gallanstown	3,352	0	0
Every other outlay, including land, engineering, law costs, stamps on bonds, implements, &c.	910	0	0
	£16,800	0	0

The actual cost of the works complete I estimate at about £10,000, this including the reservoir and all subsidiary work,

and supply main conveying the water to the Township at Harold's Cross bridge. The remaining part of the cost is for distributing pipes, valves, hydrants, and fountains in the Township, and the labour in laying them, and is heavy in proportion, in consequence of the earnest desire of the Board to supply at the outset every road, street, and place in the district, however remote or unimportant, and was also considerably increased by a special main having been run direct from the supply main to Rathgar district, in order to secure to the inhabitants of that locality (the supply of which formed no part of the original plan), the greatest possible pressure. It is satisfactory to be able to say that the proposed result has been completely attained, and every house in Rathgar can be supplied.

In conclusion, it is gratifying to the Commissioners, and must be equally so to the Canal Company, that Mr. Hawksley's opinion has been fully vindicated:

"That the water of the Canals, as proved by the analysis are of a good wholesome quality, and when taken from a proper distance from the city, and after being subject to the process of filtration, will be unobjectionable waters for domestic use, quite colourless, and of but a moderate degree of hardness."

It will have been seen that these conditions, viz., distance from the city and filtration, have been fully adopted in the Rathmines case.

Measurement of Water Mains Laid in the Township of Rathmines and Rathgar.—Total length, 21 *miles* 4 *furlongs.*

	9-in.	6-in.	4-in.	3-in.	Yds.
Anna Villa - - -	...	...	...	288	288
Appian Way - - -	...	...	...	544	544
Brighton Avenue - -	...	...	...	168	168
Bessborough Parade - -	...	...	...	120	120
Belgrave Square - -	...	...	342	174	516
Belgrave Road - -	...	...	...	159	159
Charleville Road - -	...	...	171	228	399
Castlewood Avenue - -	...	...	747	...	747

	9-in.	6-in.	4-in.	2-in.	Yds.
Cambridge Road	...	...	...	216	216
Church Avenue	...	...	189	...	189
Church Lane	...	...	...	231	231
Cullenswood Avenue	...	...	...	450	450
Chelmsford Road	...	...	...	234	234
Dunville Avenue	...	...	...	359	359
Frankfort Avenue	...	...	...	440	440
Grosvenor Road, West	...	...	...	222	222
Grosvenor Road, East	...	363	...	...	363
Grosvenor Square	...	...	15	474	489
Garville Avenue	...	...	...	237	237
Garville Avenue, Upper	...	...	66	234	300
Garville Road	...	...	...	231	238
Gulestan Terrace	...	...	...	105	102
Hawley's Fields	...	...	...	117	115
Home Villa	...	...	...	133	134
Harold's Cross	1287	...	112	592	1992
Highfield Road	...	...	792	...	795
Kenilworth Square	...	...	561	360	927
Leinster Square	...	...	159	129	289
Leicester Avenue	...	...	...	491	491
Leinster Road	...	543	516	...	1051
Leinster Road, West	...	...	...	200	207
Leeson Street	...	...	...	982	983
Leeson Park	...	...	258	309	562
Leeson Park Avenue	...	...	...	219	217
Mountpleasant Square	...	...	42	773	811
Mountpleasant Avenue	...	411	423	...	835
Northumberland Road	...	84	474	...	558
Orwell Road	...	...	226	621	840
Ontario Terrace	...	...	...	115	112
Palmerston Villas	...	...	...	192	199
Palmerston Road	..	...	...	192	191
Rathmines Road	969	...	...	930	1899
Rathmines Upper	...	308	810	609	1727
Rathgar Road	...	507	522	...	1029
Roundtown Road	...	...	...	372	372
Rathgar Avenue	966	...	162	477	1605
Richmond Hill	...	...	...	189	189
Ranelagh Road	129	363	618	180	1290
Read's Road	...	...	378	...	378
Rathmines Avenue	...	...	...	270	270
Ranelagh Avenue	...	...	...	136	136
Shamrock Ville	...	...	...	198	198
Sandford Terrace	...	...	...	408	408
Sallymount Avenue	...	...	...	132	132
Temple Road	...	...	...	585	585
Winton Road	...	...	...	273	273
Williams' Park	...	...	...	195	195
Westmoreland Park	...	...	...	39	39
Zion Road	...	...	183	..	183
					29,228
MAIN PIPE.					
From Gallanstown to the Township	...	...	...	...	8799
TOTAL	...	...	...	...	38,027

[Read February 12th, 1868.]

Description *of an* Experiment *on the* Strength *of a* Lattice Road Girder *at the* Boyne Viaduct. By Bindon B. Stoney, Member, M.A., M.I.C.E.

In the year 1858 I laid before the Institution a description of experiments made at the Boyne Viaduct on the strength of one of the braced pillars in the web of the main girders. Owing to the large scale of these experiments they are very valuable guides for future practice, and I think it may prove acceptable to the Institution if I place on record some further experiments on the strength of one of the road girders which were made by James Barton, Esq., who was then Acting Engineer of the Dublin and Belfast Junction Railway Company, the author being resident at the Viaduct.

The Boyne Viaduct is constructed for a double line of railway; the flooring, which is formed of six-inch planking, is supported by cross girders 24 feet long between bearings, and placed 7 feet 5 inches apart from centre to centre. Plate II. represents half the cross girder as first designed, and some doubts as to its strength having arisen, it was determined to test it before constructing others which might prove rather less strong than seemed desirable, considering the great weight of modern locomotives. For this purpose the girder was supported at the ends on timber framing, and the testing load was suspended beneath the four points over which the rails lie. The load was equally divided between these four points, and consisted of scrap-iron, plates, bars, &c. It would have been a more severe test of the central braces if the load had not been symmetrically distributed, but they were supposed to be amply strong for the duty they had to perform when one line of way only was charged, and the diagonals in which weakness was apprehended were those

near the extremities of the girder, which are subject to the most severe strain in the case of uniform loading.

The load in tons, with the observations made during the experiments, are given in the following table. The deflections were taken by means of a horizontal cord, one end of which was attached to one side of the girder and the other passed over a small pulley attached to the opposite side of the girder, and was kept in tension by a weight. The letters refer to skeleton diagram, Fig. 5.

EXPERIMENT 1, FIG. 1.

Date.	Total Weight in Tons.	Deflection at centre in Inches.	Observations.
1854 August 16th	20½	·10	
"	25	·15	
"	30	·19	
"	33	·25	
"	40	·32	40 tons left on all night.
" 17th	"	·32	No perceptible increase of deflection this morning.
"	46½	·32	
"	51½	·37	
"	60	·46	
"	61½	·50	
"	68½	—	Broke down, compression diagonals 2′ and 4′ buckling at *d* and *e*, and the tension diagonal 1′ tearing across at its lower extremity.

This girder is a lattice girder of the simplest form, viz., one in which two systems of triangles occur, but it will be observed that the load is supported nearly altogether by one system, only so much of the weight being conveyed by the second system as is transmitted through the flanges

acting as girders when the loaded points deflect. This amount is, of course, quite indefinite, as it depends on the stiffness of the flanges, but it must be trifling compared with that which the bracing of the loaded system sustains.

The probable account of the failure, therefore, is this. The two end compression diagonals sustained the whole weight. The lower half of one of these 2′ failed from buckling, and, consequently, by means of the flanges, the whole weight was thrown for a short space of time on the second system. Under these circumstances the compression diagonal 4′ buckled, and the tension diagonal 1′ broke across at its lower end, being momentarily subject not only to a longitudinal tensile strain, but also to a transverse strain from the downward thrust of the upper half of 2′. If the whole weight were transmitted through the loaded system, the compressive strain in 2′ just before it failed must have equalled 48 tons, and the strain per square inch have been 11·7 tons, a high result for this species of compression bar.

Experiment 2.

We have seen that one system only could be depended upon in the first experimental girder; in order, therefore, to bring the second system of bracing into action two vertical pillars were added, the fractured bars were replaced by others of the same size, and the end compression diagonals were strengthened by an inside bar, $5'' \times \frac{1}{2}''$, and of equal length with the outside bars. These three component bars of the end compression diagonals were kept as nearly parallel as possible by liners at the rivets. The compression flange also was strengthened by two narrow strips riveted so as to strengthen the four central bays, and an inside strip $4'' \times \frac{3}{8}''$ was placed between the angle irons of the lower flange. The results of the second experiment are as follows:—

Experiment 2, Fig. 2.

Date.	Total Weight in Tons.	Deflections at centre in Inches.	Observations.
1854 August 24th	20	·19	Much wind, consequently difficult to measure the deflections accurately.
"	30	·25	
"	40	·36	
"	50	·54	50 tons left on all night.
" 25th	"	·56	
"	0	·12	Load removed as the end compression bars showed symptoms of curving in an S form.

Experiment 3.

The end compression bars, which had shown indications of weakness in Experiment 2, were blocked out into a bowed form without removing the girder from its position on the timber frames. See Fig. 3. In other respects this girder remained exactly the same as that described in experiment 2. The load of 50 tons, from which it had been relieved in Experiment 2 by means of screw jacks, was lowered down again. The following table contains the observations recorded:—

Experiment 3, Fig. 3.

Date.	Total Weight in Tons.	Deflections at centre in Inches.	Observations.
1854 August 26th	50	·41	
"	60	·51	
"	"	·53	60 tons left hanging for one hour; afterwards the weight on one pair of rails was blocked up, so as to try the effect of 30 tons on one side.
"	65	·58	
"	70	·63	Bars 4 and 8 showed symptoms of buckling.
"	74	·71	
"	76	·78	
"	78	·78	Deflection same as before.
"	80	·86	Girder broke down within a few minutes after 80 tons had been laid on. The tension bars 1 and 3 broke. The end compression diagonal 2 buckled, and both flanges became broken-backed at *a* and *b*.

The section of diagonal 3 at the place of fracture = 1·38 inch.
Do. 1 do., do. = 1·66 "

Experiment 4.

The end compression diagonals not being yet sufficiently stiff to resist flexure, 2 angle irons $6'' \times 3\frac{1}{2}'' \times \frac{5}{8}''$, which happened to be at hand, were substituted for the flat bars. The end tension diagonals were also strengthened, and in place of the lining strips in the lower flange of girder No. 2, flat plates, 7″ wide, were riveted along the bottom of the angle irons and a single plate $7'' \times \frac{1}{2}''$ was substituted for the two narrow strips along the top of the compression flange.

The following table exhibits the results of this experiment:—

Experiment 4, Fig. 4.

Date.	Total Load in Tons.	Deflection at centre in Inches.	Observations.
1854 Sept. 6th	25	·10	These 25 tons suspended from W_1 and W_2 only; compression diagonal 7 showed symptoms of buckling at *c*.
"	50	·38	
"	60	·43	
"	70	·47	
" 7th	75	·55	
"	80	·63	Buckling at *c* gone; a length of the lower flange = 20′ 7¼″ extended $\frac{5}{32}$″ under this load, *i.e.*, measuring from 0 tons.
"	85	·74	After 5 hours no further deflection; slight buckling in diagonal 6.
"	90	·79	
"	95	·86	
"	100	—	The iron straps by which the weight was suspended gave way.
"	0	·25	Set of girder from 100 tons evenly distributed.

The iron suspension straps having given way, the ultimate strength of this girder was not determined, but as the weight which it did carry was considered ample, no further experiments were made, and this very cross girder is at present doing good service in the bridge. The remaining cross girders were made of nearly the same form.

If we assume that the vertical pillars supported one-half the loads resting immediately over them, then each of the end compression diagonals sustained a pressure of about 53 tons from the load of 100 tons distributed equally at the four points of loading. The weight which they really do support is uncertain, but it is reasonable to suppose that they will

have to carry a due share of the load before failure can take place in other parts of the beam.

The greatest possible load which can take place upon any cross girder occurs when two goods' engines pass each other on opposite lines. Assuming the maximum weight of a goods' engine with coupled wheels to be 30 tons, the greatest load will occur when one pair of driving wheels are immediately over a girder. The diagram, Fig. 6, will explain this—

The load on the central cross girder $= 14 + 1{\cdot}1 + 1{\cdot}2 =$ 16·3 tons.

The maximum load, therefore, which can come upon any one girder when two goods' engines pass on opposite lines $= 32{\cdot}6$ tons. In this estimate I have left out of consideration the effect of the platform, longitudinal sleepers and rails, in spreading the weight over a considerable number of girders.

Two useful deductions may be inferred from these experiments. 1st. Whenever the load (either fixed or moving) is of such a character that it rests upon only one system of a lattice girder at a time, then the other systems are nearly quite useless for the time being. In such a case either system alone should be strong enough to support the load, and it would sometimes be more economical to employ but one system of bracing and make the flange sufficiently strong to bear the passing load in the interval between two successive apices. This might occur, for example, in a braced gantry where the length of the crab carriage from centre to centre of wheels equals one or more intervals between two successive apices of the same system. 2nd. The combination of two or more distinct modes of bracing is not advisable; it is impossible to calculate accurately what strains will pass through particular bars when we do not know how much weight such distinct arrangement has to support; one part of the bracing may be overstrained while the rest is doing comparatively little duty.

[Read January 8th, 1868.]

On the Repair *of the* River Wall *at* Burgh Quay, Dublin. By I. J. Mann, C.E., Member.

So far as the author has been able to ascertain, few instances of the repair of river or dock walls are recorded; in the majority of cases, when failure occurred, reconstruction seems to have been the usual remedy adopted.

There is little doubt that repairs, such as those referred to, are always more or less hazardous, and, if unsuccessful, not calculated to improve the reputation of the engineer; while reconstruction, though not generally so economical, is, as a rule, a certain remedy.

Before entering on a description of the method of repair adopted at Burgh Quay, which forms the subject of this paper, a few instances of a similar character, though probably known to many, may be very briefly noticed.

SOUTHAMPTON DOCK WALL.

At Southampton the dock wall which failed was 38 ft. in height, constructed of brickwork and concrete bays up to the level of low water, the remainder of rubble masonry faced with granite ashlar.

It was built on a timber platform 6 in. in thickness, the front of which rested on piles, while the back rested on longitudinal sleepers laid on the soil. The foundations varied from sandy clay to sand and quicksand.

Before the excavation of the dock was completed the wall showed symptoms of moving forward, but it was thought that when water was let into the dock the wall would be sufficiently relieved of the back pressure to remain firm. This, however, did not prove to be the case, and the wall still partially moved forward. Additional engineering advice

was obtained, and a plan of attaching land ties was recommended and adopted. This consisted of drilling holes through the wall as low as the tide permitted, inserting strong iron bars with washers in front, and tying them back to buttresses of piles driven upwards of 100 feet from the wall. After an expenditure of about £10,000 the land ties proved unequal to their task, several broke, others stretched, and the wall still moved forward. Shortly afterwards a portion of the wall fell into the dock, carrying with it and destroying a large shears. Finally the wall was rebuilt of a totally different section and without any piling.

IRWELL RIVER WALL.

Another failure occurred at Hunt's bank on the river Irwell. The wall in this case was 20 ft. in height, 5 ft. thick at the bottom, and 3 ft. 6 in. at the top, and built of ashlar masonry strengthened with counter-forts. About 100 ft. of its length was pushed into the stream to a distance of 8 ft. or 10 ft. from its original site, the wall still standing. This Mr. Vignolles accounted for at the time by the accumulation of water, which, having no outlet, settled the earth against the back of the retaining wall, turning the clay into mud, which by its great additional weight forced the wall to slide on its foundation.

PENMAENMAWR SEA WALL.

The sea walls at Penmaenmawr, in North Wales, which retained an embankment of the Chester and Holyhead Railway, failed, partly on account of the violence of the sea in severe gales, but chiefly from the effects of the water which obtained access behind them. A viaduct was substituted for part, and the remainder rebuilt of a stronger section. It may be added that the sea, which formerly expended its violence on the wall now passes under the arches of the viaduct referred to, and is gradually washing away the foot of the slope, at the top of which runs the old mail-coach road.

SHANNON RIVER WALL.

A wall on the east bank of the river Shannon at Limerick failed in a somewhat similar manner to the dock wall at Southampton, and is an instance of successful repair and partial reconstruction at comparatively small cost. This wall runs parallel to the Limerick dock wall, and about 80 ft. to the westward of it. It is about 25 ft. in height, built of limestone ashlar, on piles, the natural foundation consisting of black sandy mud, under which lay a stratum of stiff clay about 2 ft. 6 in. in thickness, and below this the rock. The bearing piles were of round timber about 14 ft. long, and driven vertical, having therefore but a slight hold in the clay; when the wall was forced forward by the back pressure it carried the piles along with it. The mode of repair was the following:—The wall was taken down to within about 3 ft. of the timber platform, which had been laid at the level of low water, and a row of whole balk piles 12 in. apart, having a batter of 1 in 4, was driven in front; the heads of these piles were in contact with the face of the old wall, and carried a capping piece 12 in. square, on which rested the ashlars of the bottom course of the new wall. Thus the new wall was built on the portion of the old that had not been removed, its front being supported by the sheet piles and capping piece. Along the foot was placed a small bank of puddle, and over this a pitching of large stones forming a substantial foreshore; counterforts, each 4 ft. square, rest on a bed of concrete, and the whole of the back of the wall is lined with puddle. Its batter is 1 in 5, the back being nearly vertical, and the ashlar courses are laid perpendicular to the face. The work has been finished about two years, and no movement whatever is perceptible. The length repaired was 470 ft., and the cost £2,800. These repairs were designed by Mr. W. Forsyth, the engineer of the Board of Public Works, who kindly furnished the foregoing particulars.

CARLISLE PIER, KINGSTOWN.

The western wall of the Carlisle pier, Kingstown Harbour, constructed for the accommodation of the mail service to Holyhead, has recently shown signs of failure. This wall is built of large blocks of granite ashlar, is about 38 ft. in height, and founded on the hard sandy bottom of the harbour. The filling between the walls consists of irregular masses of granite, tipped as it came from the quarry. A very manifest subsidence has taken place, and is shown by fissures and inequalities in the surface of the pier. The failure is attributable to the scouring action produced by the paddles of the mail steamers. These vessels soon after arrival, are "swung" or turned by making fast with heavy hawsers to the pier, and reversing their engines; they are thus brought round the end of the pier to the eastern side ready for departure to Holyhead. While, therefore, there is but little motion on the part of the vessel, owing to the leverage exerted against the paddles by the hawsers, there is considerable and continued agitation of the water by the paddle floats. In this way a trench, averaging 14 ft. wide and 3 ft. 6 in. deep, has been excavated along the foot of the wall, which is thus "undercut," and, as a consequence, the lower courses are falling out and the filling subsiding. The great friction of the vessels against the pier while turning, joined to the vibration caused by the trains which attend the steamers, has no doubt helped to loosen the stones and otherwise aggravate the mischief.

The remedy adopted consists of filling the trench with large stones, carefully fitted together at the bottom by divers. This foreshore is intended to arrest the present movement and counteract any future scour. The depth of water at the wall is about 20 ft. at low water of spring tides, and the draught of the mail packets which come alongside about 14 ft.

Other instances might be adduced, and would, on doubt,

form an interesting and useful list, but the foregoing are sufficient for the object of this paper, which is by no means intended to enter on the general question, but merely on one particular case which will now be described.

The river wall at Burgh Quay, on the south side of the Liffey, and immediately east of Carlisle Bridge (see Plate III., Fig. 1), had for some years shown various signs of weakness and failure. The flagged pathway and part of the roadway had subsided considerably, the wall had also sunk and was moving slightly towards the river; its batter, which had originally been about 1 in 12, was reduced to about 1 in 30, and two raking cracks or fissures, one at each end, defined the length of the failing part. It therefore became necessary either to rebuild or repair it. The latter course was adopted, and has been carried out successfully at little more than one-half the cost of reconstruction.

The wall was built about the commencement of the present century, and consists of rubble masonry set in lime mortar, and faced with granite ashlar in 12 in. courses, carrying a parapet with heavy ashlar coping. Its section varies slightly, but the one shown in the drawing (Fig. 3, Plate III.) may be taken as the average.

The filling at the back was found to be of a very heterogeneous character, consisting apparently of old building rubbish deposited at random. Two main sewers and a smaller one empty themselves into the river through the wall; an examination of these sewers showed that they had partially sunk, and were much dilapidated at their junctions with the wall, so that as each tide flowed the water obtained easy access to the back of the wall, and, returning with the falling tide, carried with it some of the finer particles of the filling. Borings made in the bed of the river close to the foot of the wall, to ascertain the nature of the foundations, gave the following average results:—Mud, 2 ft.; blue clay, 10 ft.; sand, 2 ft.

The wall was founded about 3 ft. or 4 ft. below the upper surface of the mud, and therefore rested on a bed of blue clay, which was very probably being squeezed out from under it, accompanied by the slipping movement referred to. A few trial piles were driven without much difficulty to an average depth of 20 ft. The method of repair adopted—which was designed by Bindon B. Stoney, Esq., Engineer to the Dublin Port and Docks Board—will be understood by an inspection of the drawings (see Plate III.) and the following brief explanation:—A row of whole balk Memel piles in close contact with each other, and having a batter of 1 in 8, is driven along the foot of the wall; the piles are shod with cast iron shoes weighing 75lbs. each, and were driven with a 22 cwt. ram to an average depth of 20 ft. below the surface; they are dressed on their joint sides only. The weight of the shoes may probably appear excessive; as a general rule, however, it will be found desirable in sheet piling of this kind to err on the safe side, particularly as it can be done at comparatively little additional cost (say one shilling per pile extra). Each pile, previously to being driven, was examined by the inspector, and its length branded on it in figures every 2 ft., an over length of 3 ft. being left for reheading, &c. The piles were specified to be driven to a depth of 20 ft., or deeper if required, a deduction being made (according to schedule rate) for all piles not driven to the depth mentioned, and an extra allowance for those driven beyond it. A pile was considered fully driven when three blows from a 22 cwt. ram lifted 14 ft. failed to drive it a quarter of an inch. Ordinary piling frames were used, one of which was worked by a steam winch; each frame could drive about seven piles in two tides, or twelve hours. The tops of these sheet piles are 4 ft. above low water, at which level inner and outer permanent wales 12 in. by 6 in. are bolted to them, with 1 in. screw bolts and nuts bearing on washers head and point, passing through every alternate sheet pile

and screwed up tight, the heads and washers being countersunk into the outer wale.

Opposite the sewers the piles were cut to the level of the sills, and extra waling pieces bolted on with 1 in. bolts through every pile, the upper waling pieces being cut away so as to permit the tide flaps to open readily. All the soft mud and sand in the space between the front sheet piles and the wall, to a depth of 2 ft. below low water, was removed and replaced by Portland cement concrete well rammed. The concrete was formed of four parts clean ballast to one of cement, thoroughly mixed in as stiff a condition as possible, and put in place at dead low water of spring tides. The propriety of placing concrete in water even 3 ft. in depth, as was done in the present instance, without any protection to prevent the cement from washing out, has frequently been questioned. There is little doubt, however, that if Portland cement concrete is mixed extremely stiff, it may be thrown into moderately still water of the depth specified without suffering any serious injury. A piece of this concrete taken from the foundations of the new North Quay-wall, Dublin, 17 ft. below low water, which, immediately after being mixed, was thrown into the agitated water, running along the bottom of the cofferdam to the pumps, and exposed to its action for nearly three months, is apparently quite as good as if it had been treated far more favourably.

[The standard low water at Dublin is the average low water of equinoctial spring tides, and is 1 ft. 4 in. above the Ordnance Datum plane; the average range of the equinoctial spring tides, or the difference between high and low water is 13 ft.]

Fender piles 10ft. apart centres are placed along the face of the wall, to prevent the bilges of the vessels lying alongside from resting on the top of the sheet piling; these fenders consist of sheet piles extending 10 ft. 3 in. higher than the average; between this upper part of the fender

and the wall solid chocks of timber are fitted, held in position by cleats spiked to the longitudinal beams, the lower ends being bedded in the concrete. A chafing piece of American birch 12 in. by 6 in. 10 ft. long, with bevelled arrasses, is spiked to the outside of each fender, and the whole capped with a curved wrought-iron plate 4 ft. by 12 in. by $\frac{1}{2}$ in., the lower edge of the plate being countersunk into the timber. To enable the fenders to resist lateral pressure, strong cleats are spiked to the upper longitudinal beams one on each side of the pile. The front piling is finished at each end with a double fender. While the whole balk piles were being driven a perceptible movement of the wall took place, due probably to the continued vibration, &c., occasioned by the repeated blows of the rams. This caused considerable alarm to the contractor, who was bound by the terms of the contract to make good, at his own expense, any subsidence, &c., that might take place during the progress of the works, and for six months after their completion—the movement, however, was completely arrested by removing the filling at the back of the wall, and thus relieving it of the pressure.

Two longitudinal beams, each 13 in. square, with scarfed joints, run along the front of the wall, and two similar ones 12 in. square behind the 3 in. back sheet piling. Each horizontal pair are connected by round iron bars 3 in. in diameter, screwed at both ends with nuts and cast-iron washers. These bars are 10 ft. apart centres, suitable holes for them being jumped through the wall mid-way between the fenders. At the back the washers bear on timber washer-blocks 12 in. by 12 in. by 4 ft. (Plate III., Fig. 4). Part of the wall is slightly convex to the river, to suit which, timber having a natural camber was selected for the front longitudinal beams.

The back sheet piling consists of a row of 3 in. spruce deals, 11 in. wide and 16 ft. long, driven 24 ft. back from the face of the wall; they are shod with $\frac{1}{4}$ in. plate shoes, a $2\frac{1}{2}$ cwt. ram

being used to drive them. The back longitudinal timbers and washer-blocks are creosoted, 7 lbs. of oil to the cubic foot being the quantity specified. With regard to creosoting, it may be mentioned that the experiments undertaken by the French Government at Sables d'Olone, in the Bay of Biscay, extending over the years 1862 to 1866, have shown that the process not only preserves timber from the destructive effects of worms, moisture, dry-rot, &c., but that creosoted white woods acquire increased tenacity and elasticity, becoming, at the same time, much harder; and that in maritime works it is sometimes advisable to substitute creosoted white woods in place of oak, being not only less expensive as to first cost, but also more durable. From 13 lbs. to 34 lbs. of oil per cubic foot was forced into the timber experimented on at Sable d'Olone, the average being 20 lbs. per foot. This quantity is largely in excess of that usually put into timber in this country, which, as far as the author has had any experience, does not exceed, on the average 5 lb. or 6 lb. per cubic foot.

The longitudinal beams are respectively 11ft. and 17ft. above the foundations. It may appear at first sight that the front longitudinal beams are superfluous, as the tie bars could have been made to pass directly through the fender piles, which would then act as the beams do now; it will be seen, however, that had this plan been adopted, should any further subsidence take place in the wall—which was by no means improbable—the upper part would hang on the tie bars and remain fixed, while the lower, in subsiding, would be obliged to part from it, this result being fatal to the whole structure. The present arrangement will permit the wall to subside without further injury to itself or the piling, save drawing the spikes which fasten the curved iron capping plate to the upper beam.

The filling between the back sheet piles and the wall, to a depth of 6 ft. below high water, was removed, and

when the 3 in. piles were driven and the tie bars fixed, the space was filled with sand and gravel well rammed in 12 in. layers. The nuts on the tie bars were screwed up tight with heavy spanners about 6 ft. long, worked by four to six men. The sewers from the wall to the back piles are protected by two rows of sheet piles 8 ft. by 11 in. by 3 in., driven 1 ft. 6 in. from the side walls; this space is filled, and the top of the sewer covered, with Portland cement concrete. In one of the sewers the brickwork was found so dilapidated as to require rebuilding. (Plate III., Figs. 5, and 6). This plan of protecting the sewers answered extremely well, and though many complaints were made of flooding the basements of adjacent houses before the repairs were undertaken, none have been heard since.

The mooring rings are fixed to the face of the wall with shanks secured to cast-iron washers, bearing on heavy timber chocks behind the 3 in. sheet piles.

The wall was raised to the requisite level and weighted on the back with additional masonry, as shown by the darker hatching on the drawing (Plate III., Fig. 3). The parapet was then replaced, gaps being left in it at suitable distances to facilitate the discharge of vessels lying alongside. The road and pathway were brought to their proper level by a filling of coarse gravel, the flags of the latter replaced, and the roadway covered with ordinary metalling. The work was commenced in July, 1865, and finished in April, 1866; the length repaired is 392 lineal feet, and the contract was executed in a very satisfactory manner by Mr. John C. Morris, at a cost of £5,065.

Since the completion of the repairs the river in front has been deepened upwards of 2ft., but no movement whatever has taken place in either the wall, pathway, or road.

The author calculated as nearly as practicable what the line of pressure was in the old wall, and the arrows on the

drawing show approximately its direction; the distance between the centre of pressure and the centre of figure being about one-third of the breadth of the joint, which is rather less than is allowed in retaining walls of modern construction. The ratio of the moment of stability to that of pressure was as 1·6 to 1. The arrow crossing the lower tie bar behind the wall shows the direction of the line of pressure if the rammed gravel is considered as forming part of the structure. The formula used in the calculation was the familiar one, $P = w \times \frac{h^2}{2} \times \tan^2 \theta$. An instance of the practical truth of this formula came recently under the author's notice in the overturning of a wall by the pressure of coal heaped against it to a height of 11 ft. In this particular case correct values could be obtained for the symbols, and the result showed that the pressure exceeded very slightly the stability, the line of pressure passing almost exactly through the outer edge or foot of the wall.

The failure of the Burgh Quay wall, as also of most of the others referred to, is mainly attributable—first, to the free access of water from the front to the back; and secondly, to the foundations being of a nature easily and injuriously affected by running water.

The effect of the presence of water at the back of a wall similar to the one under consideration is obviously to increase the weight of the filling by saturation, and to diminish the angle of repose, both of which augment the pressure, while at the same time that part of the wall immersed loses by displacement more than one-third of its only element of stability, namely, its weight. The pressure of the water against the face must of course be taken into account, remembering, however, that the water falls much faster outside than inside.

In most cases a well built retaining wall may be considered water-tight, and if the water finds its way from the front to

the back, or *vice versa*, it does so to a great extent by passing under the bottom; there is, therefore, a continuous stream passing backwards and forwards, and if the foundation is such as to be thereby softened, or otherwise injured, it cannot long sustain the incumbent weight without giving way. These observations refer chiefly to walls having a variable head of water against them.

Dilapidated sewers passing through a wall form an exceptional condition, but there is little doubt that even in the particular case under discussion the water acting in the manner described above, softened the blue clay foundation, which, yielding at the point of greatest pressure, produced the observed loss of batter, &c.

In conclusion, it may be observed that it is somewhat difficult to obtain full and authentic information on the subject of repaired walls, and it is to be hoped that those in the profession who can do so may be induced to record other instances similar to the one now described.

[Read February 12th, 1868.]

An Easy Proof *of the* "Prismoidal Formula," *with an* Accurate Method *of* Taking Out *the* Quantity *of* Earth, *and of* Setting Out *the* "Half-Breadths" *in a* Cutting *with a* Steep Gradient. By Edward Townsend, M.A., Member; Professor of Civil Engineering, Queen's College, Galway.

I have found that engineering students not very familiar with geometry have experienced some difficulty in proving the formula known as the "prismoidal," which forms the basis of Sir John Macneill's and Bidder's tables. The following short method, which occurred to me, of arriving at this well-known expression for the contents of an embankment

or cutting, may be of some service to those commencing their studies in the Engineering Profession, and this, I trust, will be a sufficient apology for bringing a subject so elementary before the Institution.

In Fig. 1, which is an isometrical sketch of a cutting,

Let the constant base D C = B,

the extreme heights P C and P′ C′ = H and H′,

the ratio of slopes B P P C = N, and

the length C C′ of the cutting = L.

If we now conceive two vertical planes to pass through the lines C C′ and D D′ they will divide the cutting into a central block and two wings.

The central block is a prism whose base is the trapezium P P′ C′ C and height C D, its volume is therefore

$$= \left(\frac{H + H'}{2} L\right) B \qquad (1)$$

Let us now conceive a plane to pass through one of the extreme heights Q D, and the point A′, it will divide the wing into two pyramids, the base of one is the triangle A Q D, and its altitude D D′ the length of the cutting, its volume is therefore

$$= \left(\frac{n H^2}{2}\right) \frac{L}{3} \qquad (2)$$

The other pyramid has for its base the trapezium Q Q′ D′ D, and for its altitude the line A′Q′, its volume is therefore

$$= \left(\frac{H + H'}{2} L\right) n \frac{H'}{3} \qquad (3)$$

Adding (1), (2), and (3), and remembering that there are two wings, we get the volume of the cutting

$$= L \left\{ B \frac{H + H'}{2} + \frac{n}{3} (H^2 + H H' + H'^2) \right\}$$

Q. E. D.

A model of a cutting with the above sections shows the

whole thing at a glance, and this I have found of great service in teaching the subject.

METHOD OF GETTING THE QUANTITY OF EARTH IN A CUTTING WITH A STEEP GRADIENT.

In Fig. 2, let A B C D A′ B′ C′ D′ be the cutting whose volume is required, the plane of the base D C D′ C′ being inclined to the horizon.

As before let $PC = H$

$P'C' = H'$

$DC = B$

the length of the cutting measured horizontally $= L$, the cotangent of the angle which the plane CB B′C′ of the wing makes with the horizontal plane $= n$ it will be observed that this is not the ratio of P B to P C.

The gradient of the road $= m$.

Now it is evident that by dividing the solid in a similar manner to the last, the volume of this cutting

$$= L\left\{B\frac{H+H'}{2} + \frac{bH}{3} + b'\frac{(H+H')}{3}\right\}$$

Where $b = PB$ and $b' = P'B'$.

Conceive now a horizontal plane to pass through C, it will cut the wing in C M and the vertical plane in C T; join M T, draw M E vertically, join P E, from B′ let fall the perpendicular B′R on the plane P E M, draw R S parallel to E M, and join B′S; let the angle $MCT = \theta = EB'R$. Now, $n = \frac{B'R}{RS}$ and $m = \frac{CT}{TC'}$ hence we have

$$b' = \frac{nH'}{Cos\theta} \text{ and } b = \frac{nH}{Cos\theta}$$

We have also $Cos\theta = \frac{L}{\sqrt{L' + n^2}}$

where $n = MT$.

From similar triangles $x = \frac{Ln}{m\text{Cos}\theta}$

eliminating x we get $\text{Cos}\theta = \sqrt{1 - \frac{n^2}{m^2}}$

Substituting we finally get volume of cutting = L

$$\left\{B\frac{H + H'}{2} + \frac{n}{3\sqrt{1 - \frac{n^2}{m^2}}}(H^2 + H H' + H'^2)\right\}$$

And the half-breadths—

$$b = \frac{nH}{\sqrt{1 - \frac{n^2}{m^2}}}$$

and

$$b' = \frac{nH'}{\sqrt{1 - \frac{n^2}{m^2}}}$$

The above formula does not differ materially from the usual "prismoidal" which it becomes if we regard m as infinite. Still cases may occur where the difference would be important.

[Read April 8th, 1868.]

On Anderson's Patent Lock Arrangement *for* Railway Signals. By John Bailey, Member.

Next to working our railway system at all, it behoves us to consider the best means by which it can be in safety—as far as human foresight is allowed to go. Of course we cannot guard against accident at all times, but we may do a great deal towards it, by care and good machinery. Would it not be a great saving to many railway companies if, instead of waiting till desired by Government—in consequence of an accident—they would of their own free will place the more dangerous points of their line in a state of better efficiency? Thirty thousand pounds is no unusual amount for an action

to cost a company, and yet, in nine cases out of ten, two or three hundred pounds, judiciously expended, would have prevented it. One of the most important safeguards to railway travelling is a skilful arrangement of signals, and such a disposition of signal and point levers that, neither from accident, design, or carelessness, can casualties occur from incorrect marking of roads, or false signalling, a cause from whence springs a great percentage of the loss of human life and property annually on railways. Two or three methods of connecting signal and point levers have been in general and extensive use. I venture to draw the attention of the members of the Institution this evening to one that has been very widely adopted in this country, as well as in England and Wales, and is the invention of our worthy President, Mr. Anderson, and manufactured by the firm of Courtney, Stephens and Co., of Dublin (of which firm I am a member). It is not enough to erect signals capable of being worked correctly; the great point to be gained is, to construct and erect a machine or a system of machines, that cannot be worked wrong; in fact, to give the signalman no choice, unless it be either to let the train in on the right line or to stop it altogether. In order to illustrate the principle of Mr. Anderson's patent, I have selected the Wooden Bridge Junction House, on the Dublin, Wicklow, and Wexford line, as it contains but few levers, and consequently can be readily described. Fig. 1 represents the plan of the house, which measures about 15ft. by 11ft., having two cast-iron signal posts P and P′ which pass through the roof to a sufficient elevation, determined by the nature of the spot, and approaches. To each of these posts are attached a pair of signal arms worked in the usual manner, by means of the short levers or handles, A, B, C, and D. The left hand post, P, is for the main line, and the right hand post P′, for the branch line to Shillelagh; F and H are the levers for the main line distant signals,

E and L for the distant signals of the tramway which runs from the Avoca mines to Arklow, G is for the branch line distant signal, K the station tramway signal, and the remaining lever works the points. Each of these levers, except the ones attached to the main signal posts, pass through the floor to the cast-iron beam R, which crosses the house at right angles to the levers, the ends of the said beam being built into the wall of the house, or attached to the wood framework if there are no walls. Fig. 2.—There are suitable double jaws cast on it, between which the fulcrums of the levers are secured by means of a pin passing through them. These levers move in wrought-iron quadrants, fastened either to the floor, or to a cast-iron frame, to which can be bolted all the quadrants required in the house. The levers are secured in their various positions by a spring catch, or bolt attached to the back of each, which moves in and out of a notch cut in the quadrant. The levers are connected with the distant signals by means of galvanized, stranded, or twisted iron wire, which passes over pulleys placed about 40 ft. asunder; and to the switches by gun barrel tubing working through ground brackets or supports, with two rollers in each, one above, and one below the tube; these are placed about 14 ft. asunder. It will be perfectly clear to all present, who have any knowledge, however slight, on the subject of signals, that each and every one of these just described could be lowered from their normal state to "caution," "all clear," or raised back to "danger," by the man in charge, perfectly regardless of the consequences which may ensue from the careless performance of such an act. In order to guard against this the patent "locking" apparatus (which forms the subject of this paper) is attached, and which I will now endeavour to describe, though really its simplicity is such that a glance is sufficient to master its principles, and a moment's reflection ample to impress the mind with its utility in a signal house. The idea has been borrowed from that

beautiful—because simple—machine the "Jacquard" loom, and consists in a "selecting" bar and lever, together with a couple of guide bars secured to the under side of the floor joists, by means of cast-iron brackets. O in Figs. 1, 2, and 3 is the selecting bar, S the selecting lever, M and N the guide bars. To each signal and point lever is attached a lock rod W, which reaches from the lever to the guide bar M or N, determined by its position in the house; this guide bar has a slot cut to receive it. The point of each "lock rod," when all the signals are at "danger," is thus left protruding about a quarter of an inch on the inside of the guide bar, but not in contact with the selecting bar, which can be moved freely horizontally by means of the lever S. The quadrant by the side of which this lever works is notched on its edge to receive the lever at its various stages; there is a brass plate pinned to its upper surface, on which is engraved opposite each notch the directions for the signalman to follow, and the letters of reference of the signal or point levers which have to be moved, and to the quadrants of which corresponding letters are attached. The selecting bar is pierced with holes similar to those in the guide bars. The mode of working the apparatus is thus: it is required to let a train from the main line on to the branch line, or, in other words, from Dublin to Shillelagh; the line being in its normal state, that is, the points made for the main line and the signals at "danger." The pointsman looks on the brass index-plate, Fig. 4, for "branch line," "Dublin to Shillelagh," under which he finds the word "points," and the letters C and F; he then brings the selecting lever into the notch corresponding to this indication, and by that act places some of the holes in the selecting bar opposite the lock rods of the signals and points to be moved, at the same time making a blank opposite the rest of the lock rods in the house, which prevents them from being shifted. But the levers thus set free must be

worked in a particular order; the points must be made before the signals are lowered, and to ensure this being done, the holes which come opposite the lock rods of C and F in the selecting bar, are cut a little lower than the holes in the guide bar, consequently the signals cannot be moved till the selecting bar has been raised, say a quarter of an inch. This is accomplished by tapering the end of the points' lock rod which acts as an inclined plane, up which the selecting bar travels, so the man in charge must first make his points, after which he can make his signals C and F. It now becomes necessary to lock the points, in order to prevent them being shifted back to their former position while the signals are down and before they have been replaced to "danger." To accomplish this a notch is cut on the upper side of the points' lock rod, immediately under the guide bar N, and the lock rod of the station signal C is tapered at the end in the same manner as the points' lock rod, so that by the act of lowering the station signal C the selecting bar is again raised, and the notch in the points' lock rod comes in contact with the guide bar N, which most effectually locks the points during the time the signal is lowered. Thus by simply shifting the selecting bar you can make any number of combinations among the levers, no matter how numerous they are, and without adding any machinery for new combinations. When the points are required to be worked without the signals—that is to say, when they are required for shunting—the selecting lever is moved into the notch, opposite to which is marked the word "shunting," which causes a blank in the selecting lever to be opposite each lock rod in the house, excepting the one belonging to the points. As the lowering or raising of all in any of the remaining signals is more or less a repetition of the simple process just described, it is quite unnecessary for me now to revert to it. If the number of levers in a house exceeds twenty, it is best, in most cases, to divide the selecting bar

in the middle, and to have two selecting levers, one at either end or both in the centre. It is also advisable, when it can be accomplished, to put all the levers in a row, and working in a cast-iron frame, which can contain the selecting bar, lock rods and all the whole machine can then be fitted up in the shop, leaving little or nothing to be done out but the placing of it in position, and attaching the wires, gun barrel rods, &c., leading to the signal posts and switches. Figs. 5 and 7 shows it thus arranged: The president's system of locking possesses several advantages over any other method. In the first place it can be worked by a perfect stranger, because the selecting lever not only indicates all the operations to be performed for the passage of any given train, but frustrates every attempt to begin with the wrong levers. Secondly, *unlike all other systems*, the lever that makes the selections has no other functions to perform, and is not therefore liable to be strained and thrown out of adjustment by actuating points or signals. Thirdly, the stroke of the lever is not limited, a very important and unique advantage in distant signals and distant points levers, where not only the lengths traversed, but the portion of the quadrant over which the traverse takes place, varies with changes of temperature, stretching of wires, &c. Fourthly, it is extremely easy to change the combinations among the levers, a point of some importance on main lines, where the Government inspectors very frequently order changes to be made in the mode of working junctions; these, with the apparatus I have endeavoured to describe, can always be made in a few hours, by simply cutting the necessary holes in the selecting bar In the case of the Wooden Bridge Junction, owing to the distant signal G on the branch line being so far round the curve as not to be visible from the house, it became necessary to put what is termed a "repeater" G^1, that is, an auxiliary signal worked back from, and by, the levers of the distant signal; this repeater is placed within sight of the

signal house, and by its movement the man in charge knows whether his distant signal is working correctly or not. Galvanic repeaters are often used, but they are very liable to get out of order, and therefore ought not to be adopted, when it is practicable to employ an auxiliary signal. Fig. 6 represents a points indicator, a small signal which seems often to be sadly neglected, or rather not sufficiently appreciated. It is placed directly opposite the points, and is worked from the end of the switch rod direct. The engine driver can tell for a considerable distance for which road the points are set, and also if they are perfectly closed or not, which is at once apparent by the moveable arm coinciding or not with either of the fixed ones. All distant signals should be placed 500 yards before facing points, or from a station, unless the approach is situated on a great incline, when the distance should be exceeded in proportion to the steepness of the descent. The signal posts manufactured by us are really the only durable ones constructed, being of cast-iron; they are 8in. in diameter externally at the bottom, and 6in. at the top, the thickness being about ½in.; they are most unique in appearance and substantial throughout. Fig. 8 represents what may be termed an anti-expansion and contraction lever, which is also patented by Mr. Anderson. It consists of a drum or wheel mounted loosely in a cast-iron frame, by means of a short horizontal shaft B; round this drum is lapped a chain on wire C, leading from the distant signal, and to the pendent end of the chain is attached a tension weight W, of cast-iron, which causes the chain to grip upon the drum or wheel. To the shaft B is attached a radius arm D, from which a bent guard, E, projects to act as a stop to its backward movement, and preventing its falling over or past its normal position. Connected to the upper end of this radius arm by a fulcrum pin is a weighted hand lever F, the lower end of which forms a click, and serves to act upon a ring of ratchet teeth formed

on a flange of the drum or wheel A. To prevent the weighted lever falling backwards out of the reach of the signalman, and yet to allow of its having a motion independent of the radius arm to which it is pivoted, the lever F is furnished with a pin which takes into a short segment slot in the radius arm D, and acts as a stop to the falling over of the lever away from its work. In order to change the lower or distant signal, the signalman, grasping the handle of the lever, pulls it forward and engages the catch with the ratchet teeth as shown in dotted lines, he then draws down the lever, and thereby rotates the drum or wheel, continuing the action—through a large arc if required—until the signal is changed. The weight of the lever D being thus thrown over, will tend to keep the chain taut, and the signal in the required position, but the lever apparatus will still be free to yield to any undue tension put on the chain owing to the variations of temperature or other causes. By raising the lever the chain will be free to run back and permit the signal to recover its normal position. Any slackness of chain that may occur by tension, or other cause, will be taken up by the loose drum, owing to the continuous drag of the weight W, whether the strain of the weighted lever F be upon the chain, or removed therefrom. This drum or wheel can be made to work in connexion with the selecting apparatus by keying to the axle B a short arm K, to which is attached a pendent rod P, which is connected to a bell-crank lever, which works a horizontal rod that is intended to play through the selecting bar in the same manner as the other lock rods. Nothing can be more simple, or more certain to answer the purpose for which it is intended, than this wheel lever: in fact, it is the only thing of its kind which will take in any amount of slack. In conclusion, I may add that Government inspectors have spoken in the highest terms of this locking apparatus, and that many engineers on the Lancashire lines have become alive to its

advantages, and are fast adopting it. As regards expense I have no hesitation in saying that it is by far the cheapest locking system in use, when compared with the amount and certainty of its work.

[Read December 9th, 1868.]

On the METHOD *of* PREVENTING *the* BURSTING *of* DOMESTIC WATER-PIPES *by* FROST *or* PRESSURE.—By G. H. KIDD, M.D., Fellow of Royal College of Surgeons in Ireland.

I CANNOT appear before the members of this Institute without feeling that I owe them an apology for so doing, for I am indeed quite ignorant of the very rudiments of engineering science; I shall not, however, waste time with excuses, but simply ask indulgence for my deficiencies, for I have full confidence that if my suggestions have any merit they will be accepted, even though I am not a member of the profession to which the consideration of such subjects more especially belongs.

The question is not, however, altogether foreign to my own professional pursuits, for the perfection of the arrangements for the supply of water is too closely connected with health to be overlooked by the physician; and the domestic and economical importance of the subject is sufficient to interest us all.

Twice during the winter of 1866-67 I had my house flooded by the bursting of a pipe leading from a cistern at the top to the housemaid's sink, whereby the ceilings, furniture, and walls were seriously injured; and during the same season the supply of water through the house was cut off for a considerable period in consequence of the obstructing of the rising main by the freezing of its contents, whereby I was not only put to great inconvenience and considerable expense,

but exposed to derangement of necessary and healthful habits.

When my attention was thus directed to the matter I found that my experience of frozen pipes was not singular, and that no efficient remedy for the evil was known. In the course of my inquiries I was informed by the pipe-water authorities in Glasgow that in the same season—1866-67—they were applied to, in the course of one night, by the occupiers of 280 houses, to cut off the water on account of pipes burst by frost; and my informants stated that they had reason to believe the houses where the occupiers cut off the supply themselves, when they discovered the pipes to be burst, far exceeded this number. In the same season, a writer in the *Times* newspaper (7th of January, 1867), stated that it costs half a million of money sterling per annum to repair the damages done in London to houses, furniture, and shop goods by the bursting of pipes during the winter frosts; and one of the most eminent physicians in Edinburgh told me that scarcely a winter goes over without his having "two or three (to use his own words) inundations" from the freezing and bursting of the pipes used to distribute water throughout the several rooms in his house.

These facts sufficiently illustrate the importance of protecting water-pipes from the effects of frost; but it must be obvious that to protect them from the effects of pressure is of scarcely less importance, especially where, as in Dublin at present, the system of supply is being changed from one of low to one of high pressure. It is true that the risk from this cause may be obviated by increasing the strength of the pipes themselves, but no strength of material that can be used will be capable of resisting the expansion of water in passing from the fluid to the solid state under the influence of diminished temperature; and even if both objects could in this way be accomplished, it would be but a clumsy method

compared to one whereby the causes of the bursting are removed, and so the accident itself prevented.

The objects to be attained in a perfect system are two-fold:—

1st. To protect the pipes from being burst by the freezing of their contents.

2nd. To protect them from being burst by pressure.

Two sets of pipes have to be provided for:—

1st. The rising main, or supply pipe, carrying the water from the street main to the house cistern.

2nd. The distribution pipes, or those carrying the water to the several points where it is required through the house.

The methods ordinarily in use for supplying houses are two-fold:—

1st. To have a pipe brought through the house from the street main, and have taps on it, from which the water may be drawn directly wherever it may be required. This is a plan so bad and so dangerous that it should never be adopted but by *those who are willing to find themselves all drowned some fine morning when they awake!* The second plan is a little less dangerous, but in this respect has not much to boast of. It is the one most generally used. A cistern is placed at some convenient point—generally at the top of the house; to this a pipe, called the rising main, is brought up from the street main, on the end of which, at the cistern, a ball cock is placed, and from the cistern the water is conducted by distribution pipes wherever it may be required. Under this system the two sets of pipes are always full of water, and this may be at rest in them for hours, and consequently be in the most favourable condition for being frozen. Moreover, the rising main has not only to bear the whole pressure of the column of water reaching from the ball cock to the reservoir, but also the shock produced by the reaction of the current each time the ball cock is closed.

The system I propose is to place two cocks on the rising main, or supply pipe, where it first enters the house. These cocks are worked by a ball placed in a small tank and connected with the cistern at the top of the house by an overflow pipe, for which purpose the ordinary notice pipe is quite sufficient. When the house cistern is full water flows down through this overflow pipe, and fills the tank, whereby the ball is raised and the supply cut off. By the same action the second cock is opened and all the water lying in the rising main is allowed to run off; so that this pipe is kept empty except when the water is actually running. By this arrangement the rising main is absolutely safe from frost, because it is emptied the moment the supply is cut off; and it is equally safe from pressure, because the mouth of the pipe is always open, and the water has no resistance to overcome but that of its own weight.

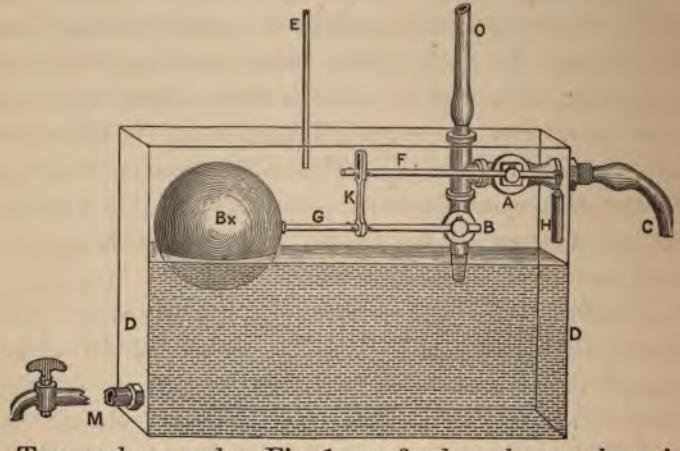
To turn on water into the house it is only necessary to draw off some from the small tank, in which the ball cock is placed. This, in point of fact, involves no more trouble than does the turning on of gas before lighting it; but to ensure its being done frequently in the course of the day the tank is placed in the kitchen or scullery, and is made the only source from which water can be obtained in the basement-story for any purpose. But as this tank contains only a few gallons of water, and the servant may at times require a much larger supply, the exhausting cock is made with two apertures, so that when all the water in the tank has been drawn off the cock opens and a supply is obtained direct from the main. When the servant has obtained a sufficient supply and closes the tap this cock closes and the water runs, as before, into the house cisterns till they are full. Thus every time the water is used in the kitchen it is turned on into the house, and continues to run till all the house cisterns are full, when it is shut off by its own action, and the pipes

are emptied without any special care, attention, or knowledge on the part of the servants. The requirements of the kitchen ensure the water's being turned on frequently through the day, and the arrangement of the two-way cock affords an unlimited supply for kitchen purposes.

The rising main being thus perfectly protected both from frost and pressure, it remains to be shown how the distribution pipes are also to be preserved. In public buildings, where they have to run considerable lengths, and in private houses, where they are placed near the slates, or in other exposed situations, the distribution pipes are as liable to suffer from frost as the rising main, and for perfect safety they must be kept empty. For this purpose small cisterns must be placed wherever a supply of water is required. If it be in a dressing-room, the back of the wash hand stand may easily contain the cistern; and in like manner in other situations it may be easily placed where it will neither be an obstruction nor unsightly. These cisterns may be supplied in one or other of two ways. A branch may be taken from the rising main to each, and a ball cock placed in the cistern. In this case, when the water is turned on, it first flows into the lowest cistern till it is full and the ball cock is closed; it then rises to the next level, and so on fills each in succession till it arrives at the highest one of all; here the mouth of the pipe is still left open, and when the cistern is full the overflow cuts off the supply, as already explained. In some situations a still better plan may be adopted; the several cisterns may be filled by the overflow, and when the lowest cistern is full the overflow from it may pass down to the tank to cut off the supply when it enters the house. By either plan the distribution pipes will be perfectly protected both from pressure and frost; but by the second the use of ball cocks will be entirely done away with, which is no mean advantage where it can be accomplished. Like most other inventions it has

been found possible to simplify the apparatus in the actual working of it. For its present form I am greatly indebted to the suggestions of Mr. Standing, one of the apprentices in Messrs. Edmundson's, where it is manufactured. It is now as simple in construction as any ball cock apparatus could be; in fact, it is simply the ordinary ball cock brought down from the top of the house to the bottom, and so placed that if it should happen to become stiff, as all ball cocks are liable to do, it is easily got at to be freed. It is easily attached to existing pipes in houses, and the ordinary notice pipe already existing in all cisterns serves as the overflow pipe. The following diagrams will serve to show the construction of the apparatus:—

Fig. 1.



Two cocks, A and B, Fig. 1, are fixed on the supply main, C, as near as may be to where it enters the house, and a small cistern or tank, D, placed underneath them, into which an overflow or notice pipe, E, is conducted from the highest house cistern. This regulating tank or cistern is of cast-iron, of about the same dimensions as the cisterns used for regulating the supply of water to kitchen-range boilers; it is 22

inches long, 14 deep, and 8 wide. The supply main from the street is brought through an opening at one end of this cistern, and has the stop-cock, A, placed on it there. One of Guest and Chrimes' screw-down ball-cocks, or some other form of high-pressure cock, may be used here. The exit end of this cock is connected by means of a T-shaped junction with the rising main, O, and with a two-way ground plug cock, B, of which Fig. 2 shows a section. This cock, B, is connected by a lever rod, G, with the copper ball, B′, which is 6 inches in diameter. The cock, A, has also a lever rod, F, which at one end carries a weight, H, and at the other is connected by means of a link, K, with the lever rod, G, of cock B. Fig. 3 is a front view of this link, and shows a slot through which the lever, F, passes. Pins passed through the lever rods, G and F, on each side of the link keep it in its place. M is a pipe leading from the regulating tank, and closed by an ordinary bib-cock. This pipe may be conducted to any distance, or have any number of branches; and all the water used in the basement story, either in the kitchen or scullery, in the boiler or in the servants' water-closet, is obtained through this pipe, M, or its branches.

Fig. 2 shows a section of cock B. The apertures are so

Fig. 2.

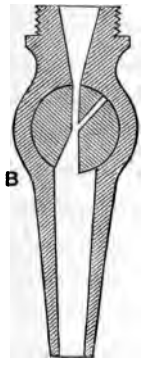


Fig. 3.

placed that when the tank, D, is full, and the ball raised, there is a free passage for any water there may be in the rising main, O, to escape into the tank; but when the ball is in this position the stop-cock, A, is closed, and no water enters, and none can escape but that lying in the pipes. On the other hand, when the tank, D, is empty, and the ball falls, the cock, A, opens, and the cock, B, also opens by virtue of the second way, and a continuous stream passes from the main into the tank, D, and thence through M, if it be open, affording a supply direct from the main for kitchen and other purposes. As soon as sufficient water has been obtained, and M is closed, the tank D begins to fill, and the ball rises sufficiently to close the cock B, but, in virtue of the play room afforded by the slot in the link, K, does not affect the cock, A, which still remains open; and now the water passes through the rising main till it fills the house cisterns, when the overflow comes down by the pipe E, and filling the tank, raises the ball till it closes the cock, A, and opens the cock, B, when the pipes empty themselves. Thus the whole action is automatic, and requires no attention or knowledge of the process on the part of the servants; and as no water can be obtained on the basement story except through M or its branches, the house cisterns are filled every time water is drawn in the basement story, and are kept full without special attention. The weight, H, prevents the cock, A, being opened by the pressure of the water when the weight of the ball, B′, is taken off it, and also closes the cock slowly and gradually.

When the supply is only afforded during certain hours in the day, there need not be two channels through the cock, B, as it is only necessary to have it open when A has been closed. In this case there should be a cistern in the basement story sufficiently large to hold a day's supply of water, and the regulating tank, D, should be placed immediately above

this large cistern. A branch must be taken from the rising main, O, for the supply of this cistern, and have an ordinary ball-cock on it. The pipe, M, must be permanently open, and be of such a size that it will take the tank, D, some time to empty itself. It may discharge into the large cistern. As soon as the water is turned on in the street it will pass the cock, A, into the rising main, and thence through the branch to the large cistern. As soon as the cistern is full the ball-cock placed on it closes, and the water rises to the cisterns on the upper stories, filling them in succession; and when the highest is filled, the overflow comes down and fills the tank, D, raises the ball, B′, closes the cock, A, cutting off the supply, and opens the cock, B, so as to empty the pipes. The tank, D, now empties itself slowly and gradually, and by the time the supply is turned on again the ball has fallen, the cock, A, is open and B is closed, so that the water can enter the house till all the cisterns are filled.

In conclusion, I claim for the invention—

1st. That it is original in design.

2nd. That it is simple in construction, and little liable to go out of order.

3rd. That it perfectly protects the two sets of pipes—the rising main and the distribution pipes—both from frost and pressure.

4th. That its use renders it unnecessary to change the pipes in any house because of a change from a low to a high pressure system of supply.

[Read December 9th, 1868.]

On a SELF-ACTING REGULATOR *for the* SUPPLY *of* WATER *at* HIGH-PRESSURE.—By CHARLES GEOGHEGAN, Associate.

THE important question of water supply at high-pressure

having of late years much engaged public attention, and the serious and frequent cases of failure in pipes, cocks, and taps, from the excessive strain of an inconstant force, whether caused by the fluctuating altitude of the head of water, the expansion of confined air within the pipes, or the still more subtle effects of frost, have led many to attempt to moderate these dreaded evils, by means of reducing the pressure of the fluid passing through the conduits; and here it is important to observe that the chances of failures are increased during the hours of night, in consequence of the greater number of services in daily use being closed, the result being that the head of water in the mains become more elevated, causing the distress upon the pipes and cocks to be at the greatest possible height; and so numerous are the difficulties to be encountered in the endeavour to provide against every difficulty, that any efforts which have been hitherto made public, can only be considered as partially successful.

I have, therefore, ventured to lay before you this evening, the result of my humble efforts to improve upon what has already been partially achieved by other learned investigators on the subject of high-pressure water supply, believing that any useful appliance to save the enormous amount of damage to property caused by failure in the system, from whatever cause, might be regarded by the public as "a step in the right direction" towards the solution of a problem which has long perplexed many patient and skilled investigators.

We have had so little experience in this country of the effects of pipes bursting from excessive head of water, that no calculation can be made as to the extent of damage to property, independent of the waste of water. Any casualties that have occurred so far, being confined to defects in street mains, which, although inconvenient, are beyond the reach of injury to our dwellings; and I am not aware of any effectual means of reducing the strain upon the large conduits conveying

the water from the reservoir, the pressure upon which must be represented by the constant head of water maintained at the basin, from which they are laid.

Provision by mechanical means has been made to allow of the escape of confined air from the pipes, which has been found a dangerous element in the system of water supply; but until some perfectly reliable self-acting valve has been found to permit the air to be let off without causing a waste of water, this subject will remain a cause of anxiety to the hydraulic engineer.

It was my intention, during the past session, to have brought before the Institute the very novel and ingenious invention of Dr. Kidd, for relieving pipes from the effects of pressure or frost, but as this matter has been more ably laid before you by the inventor himself, the merits of each system will now become the subject of your valuable opinion.

It must be evident that any means of water supply to be at all times available, should be constant and self-acting; experience having proved that a system dependent upon personal attention will be open to neglect or abuse, the result being that confidence in its successful action becomes weakened, and that which was in itself good, is cast into disuse for not being perfect, and therefore it occurred to me to endeavour to provide some means for ensuring a self-acting valve or inlet, which would not be liable to any of the objections which have hitherto been raised against the means of saving existing pipes and fittings, and the result of my experiments it will be my privilege now to submit to this assembly, comprising so many eminent, scientific, and practical authorities.

In order to provide for a proper supply of water under all the circumstances of household requirements, it is necessary that the main inlet should be so arranged that it may fill the highest cistern of any building, not depending on the action of any mechanical means requiring personal attention on

the lowest story or basement. As it frequently occurs that our kitchen, offices, &c., are situated on the upper floors, while little or no water may be used on the lowest stories, and therefore if at any time the upper cistern be left without water, the effect will be that the boilers become cracked when the cold water is admitted; the closets smell for want of daily flushing, and the baths are left without hot or cold water, when perhaps the most urgent demand occurs for their use.

To insure a full cistern at all times, the little mechanical contrivance now introduced to your notice, has been designed, which will admit of a constant flow of water at high-pressure, closing the main inlet when the cistern has been filled, and exhausting the rising main or supply pipe each time the full quantity has been admitted, leaving the pipes consequently free from the effects of frost when exposed in winter. A small pipe and cock being fitted to the exhauster to admit of this provision, being closed during the summer months, when no danger may be anticipated.

The action of the regulator is as follows:—

The water at high pressure being admitted through the valve (*a*) of the apparatus passes up to the highest cistern to be supplied, from which all other branch pipes may be taken at ordinary pressure. An air box, 11 inches by 11 inches, is placed in this cistern, inverted, and firmly secured by straps and screws to the top of the cistern, the warning pipe being united to the air box, is carried down and attached to the lower chamber of the regulator, which is divided from the upper by a diaphram (*e*), a tube (*f*) being fixed in the centre for the guidance of the spindle to which the ball is secured, and which also allows the water to pass from lower to upper chamber under floating ball. As the cistern becomes filled, the air confined in the inverted box being condensed by the pressure of the head of water rising 4 or 5 inches above the open bottom, is forced down the warning pipe into lower

chamber of the apparatus, depressing the water in same, and causing it to ascend in upper chamber, in which the ball floats, connected with the high pressure valve. As this cock closes it raises the balance tube (*c c*) charged with mercury above the horizontal position, allowing the mercury to fall over to the other end of the tube; the momentum of which, acting upon the lever of the exhaust cock (*d*), causes it to open after the main inlet is closed, and thus empties the rising main from the regulator up to the cistern.

As water is drawn off from the cistern, the condensed air becomes liberated, the ball again descends, the exhaust cock closes by weight of lever, and the inlet opens as before.

The vast quantity of water wasted throughout the city, from the neglect of due precaution, has induced the Water Works' Committee to impose heavy fines on all parties admitting of leakage, from whatever cause, the constant escape of water from high pressure cocks, of even the most approved principle, having already been the cause of serious complaint. Ample provision having been made for the present and increasing wants of the population of this city, but no possible storage can be made for that quantity of water which may be lost through the numberless cocks or pipes continually wasting.

[Read 13th Jan., 1869.]

SHORT HISTORICAL SKETCH *of the* CONSTRUCTION *and* WORKING *of the* BANN RESERVOIR *at* LOUGH ISLAND REAVY, COUNTY DOWN, *with the* DESCRIPTION *of a* LONG-EXISTING LEAK *in the* MAIN EMBANKMENT, *and its* REPAIR *in* AUTUMN, 1867.—By JOHN SMYTH, jun., Member, M.A., F.M.S.

LOUGH ISLAND REAVY, Fig. 1, the chief reservoir for the

supply of the River Bann, is situated at the foot of the Mourne Mountains, to the north-east of the axis of the chain, at an elevation of 440 feet above the sea level. Its present extent, when full, is 253 acres, supplying 38 feet 6 inches of its depth for the use of the mills. When this is run off, the area is reduced to 93 acres, the size of the original lake. It is the property of the Bann Reservoir Company, which was formed in the year 1835 by the millowners on the River Bann, who suffered great inconvenience and loss from want of water, at irregular, and in summer frequently recurring, periods. The first meeting was held on the 16th November, 1835, when the provisional committee was formed, consisting of the following members:—Thomas Crawford, George Mulligan, Edward Clibborn, Richard Hayes, Hugh Dunbar, Frederick Hayes, John Smyth,* Samuel Law, Benjamin Haughton, Isaac Stoney, John Christie, and Thomas Wakefield, jun. These gentlemen were the principal fallholders then on the River Bann, and deeply interested in the success of the undertaking. They placed themselves in the hands of Wm. Fairbairn, Esq., C.E., F.R.S., who employed John F. Bateman, Esq., C.E., F.R.S., to survey the River Bann, its tributaries, and their several collecting grounds, and made an exhaustive report of the water-bearing resources of the district. He recommended the construction of two impounding reservoirs, Lough Island Reavy and the Deer's Meadow, and one auxiliary one, the Corbet Lough. With the exception of the Deer's Meadow, which was abandoned, as being too limited in supply and expensive in construction, his recommendations were carried out, and Lough Island Reavy was finished in the latter part of the year 1839, and the Corbet Lough about the year 1847. A detailed description of these works is contained in a paper by Mr. Bateman,

* The Author's Father.

contributed to the Institution of Civil Engineers, an extract from which is published by Robert Mallett, Esq., F.R.S., in the 6th Vol. of *Papers on Engineering*, edited by John Weale in 1849. In Sir Robert Kane's work on the *Industrial Resources of Ireland*, a portion of Mr. Fairbairn's report is given, containing the data on which he based his calculations, and the estimates for the several works. I would remark, in passing, that nearly thirty years' experience in working the reservoir has more than borne out Mr. Fairbairn's calculations, as a glance at the accompanying table and diagram Plate 9, compiled from the Register, will show. No register was kept previous to 1847, so we can only take the average of 21 years. No rain-fall observations had been regularly kept at Lough Island Reavy before Mr. Fairbairn made his report, so he took the average of Ireland (36 inches) as the basis of his calculations. I have, however, kept a rain gauge at Lough Island Reavy since the 1st May, 1861, and find the average fall to be 48·2 inches; and as the collecting ground of Lough Island Reavy is 3,300 acres, and the capacity of the reservoir 288,000,000 cubic feet, the total rain-fall would fill the reservoir twice in the year; or, allowing $\frac{1}{6}$th for absorption and evaporation, as Mr. Fairbairn has done, $1\frac{2}{3}$ times instead of $1\frac{1}{2}$ times, as he had anticipated. It is manifest, however, from the results already attained, that $\frac{1}{6}$th is too little to allow for evaporation and absorption. To determine this amount as nearly as possible, it is intended to erect in the delivery feeder a weir board where the caretaker can measure the quantity discharged by allowing a certain fixed depth to pass over; this he can enter in his book, instead of, as at present, so many inches open in each pipe. The difference between the rain-fall and the discharge will then show the amount of evaporation and absorption.

In the table the first column gives the date, which commences with May, 1847; the second column shows the

Working of Lough Island Reavy Reservoir for 21 years.

Year	Number of days more water than 4 inches in one pipe was run off	Number of days Lake empty	Number of days stopped when below 15 feet, as per bye-law in 1862	Number of days gratuitous running of 4 inches or less for small mills on Muddock	Number of days full	Highest level of lake, and day attained	Ft.	in.	Lowest level, and day attained	Ft.	in.	Rain-fall	Dividend paid Share-holders Per cent.
1847 from May 22	115	19	—	55	0	May 22,	35	4	Sept. 21,	0	0	—	0
1848	39	0	—	262	0	Dec. 25,	35	3	Jan. 1,	23	6	—	—
1849	85	0	—	169	58	April 9,	38	6	Sept. 30,	17	0	—	0
1850	121	61	—	100	0	Feb. 23,	30	0	Sept. 7,	0	0	—	2½
1851	65	0	—	16	0	May 13,	30	3	Sept. 30,	7	0	—	2½
1852	110	0	—	59	0	Dec. 31,	37	6	June 1,	10	6	—	0
1853	160	0	—	75	40	Jan. 4,	38	6	August 31,	8	3	—	2
1854	167	38	—	42	12	March 17,	38	3	Sept. 30,	0	0	—	2½
1855	93	0	—	4	0	June 25,	25	0	Sept. 28,	9	0	—	3
1856	96	0	—	14	0	April 23, 29,	35	0	Sept. 23,	11	3	—	3
1857	119	10	—	5	78	March 14,	38	6	Nov. 21,	0	0	—	3¼

1858	88	0	—	0	0	June 4, 21,	29	9	Nov. 24,	10	0	—	0
1859	86	46	—	1	10	May 7,	38	0	August 8,	0	0	—	3½
1860	105	0	—	30	15	April 14,	38	3	Jan. 1,	17	6	—	3
1861	52	0	—	123	81	Feb. 21,	38	3	June 23,	16	0	—	3·4
1862	121	0	—	48	211	Jan. 1,	38	3	Oct. 11,	23	3	52·9	3·4
1863	189	10	—	54	0	April 3,	36	9	Sept. 21,	0	0	42·8	3·4
1864	124	13	12	7	0	April 21,	35	9	Oct. 5,	0	0	44·7	3·4
1865	129	2	14	2	34	March 8,	37	6	Oct. 7,	0	0	52·3	3·7
1866	100	0	0	6	97	Feb. 1,	38	6	Sept. 3,	5	6	54·6	3·8
1867	105	42	0	1	86	March 28,	38	6	Nov. 2,	0	0	47·2	3·7
1868	93	6	0	0	0	Dec. 31,	31	3	August 12,	0	0	43·3	2·8
21 years	2,247	228	26	1,018	722	—			—			337·8	—
Average	107	11	5	48	34	—			—			48·26	—
1	2	3	4	5	6	7			8			9	10

number of days more water was delivered than a small gratuitous supply of four inches or less (out of one of the 18-inch pipes), granted to some little scutch mills, which still continued in precarious existence on the discharge race or old Muddock River. During the days noted in this column the quantity discharged ranges generally from 6 inches to 10 inches in each pipe. When the lake is half full, 8 inches in each pipe gives about 60 feet per second, the amount agreed upon as necessary for the average sized mills, and also that which the Muddock will conveniently vent. The average number of days this supply was given is 107; and when we remember that for the greater part of these a full supply was run off, it must be acknowledged that this reservoir is and has been of immense value to the millers on the River Bann; indeed, whilst the average value of water power for Ireland is about £2 per horse-power per annum, in this case it may be estimated at £4 where only 10 hours' work per diem is available, and £7 where 24 hours, or constant work, is maintained. This value is exclusive of the water-tax, which at the present assessment of £10 per annum per foot, would be £1 5s. per horse-power where 8 horse-power per foot is obtained; so the respective values would be £5 5s and £8 5s. to those free of the tax. Steam power on the Bann costs about £6 per annum per horse-power, calculating 4 lbs. of coal equal to 1 horse-power per hour. The first cost and maintenance of works necessary to render these powers available would be greater in the case of steam than water, and would make up for certain disadvantages attending the latter. This point is well treated in Sir Robert Kane's work on the *Industrial Resources of Ireland*, p. 99, where the letting value of steam in Glasgow is given at £36, and the possible remunerative value of water power in Greenock is £5 6s. 5d. In the same locality water power, where it is constant, is as

valuable as steam; the latter can be made available, however, in many places where the former cannot. Column 3 shows the number of days in each year the reservoir has been entirely empty—11 is the average; and as the mills are generally put on short allowance for some time previous to these failures, that number may be doubled. By good management, however, these failures can be almost altogether prevented, as will be seen to be the case of late years, if we except 1867, when the repairs were carried out. Column 4 shows the number of days the water was stopped, in accordance with a bye-law passed in 1862, that the reservoir should not be drawn lower than 15 feet before the month of August, to meet the objections of corn and scutch millers, whose business does not commence till that season. These days, of course, should be added to those on which the reservoir was empty, to show how long it failed to give a supply. Column 5 shows how many days the gratuitous supply of 4 inches and under in one pipe has been granted to the small mills mentioned above; the Directors, however, have put a stop to this since 1863. In some few cases when the large mills, which are all below the Corbet Reservoir, are drawing their supply from it, a small supply from Lough Island Reavy must be given to two scutch and corn mills above the Corbet Reservoir. Column 6 shows the number of days the reservoir was full in each year; the average is 34, which is much in excess of the days it was empty. For some years back the sluices at the head of the feeders have been closed when the lake fills, as the Company were obliged to pay large damages some years ago to the landholders, whose fields were flooded; there was no room in the reservoir to receive the surplus water which ran over the waste weir, and for its damages they were held responsible. Column 7 shows the highest level attained in each year, and the date on which it occurred; 38·6 inches is the highest point to which the lake can be

filled. Column 8 shows the lowest level, and also the date when this occurred, or when it was empty altogether. Column 9 gives the rainfall for as many years as it has been observed; the average is 48·2 inches, very much in excess of the average of Ireland and also of Banbridge, which is 29·3. Column 10 shows the dividend paid on the shares in the Company each year—averaging about 3 per cent.; it is not very encouraging. It is, however, expected, when the Banbridge Extension Railway has been completed, that all the falls on the river will be occupied, which is not nearly the case at present. Another, and indeed the principal, cause of the bad dividends was the large sums the company were compelled to pay for flooding the lands on the banks of the Muddock between the reservoir and the River Bann; a great part of its course abounds in elbows, and for three miles has scarcely any fall; indeed, the floods of the River Bann itself flow back to this distance. The Directors found out, a few years ago, that they need never have paid these damages, as they were not responsible for the filling up of the River Muddock, nor bound to scour it, as they had often done at a very heavy expense. One principal and three smaller embankments were required to impound the water to a height of 35 feet above the original lake. These embankments were all constructed much alike, so that the description of No. 1, Figs. 1, 2, and 3, the principal one, will be sufficient. It is about 700 yards long and 40 feet deep at the discharge culvert, where it attains its greatest height; the foundation was good, and the puddle trench was sunk in it to a sufficient depth; the puddle is 12 feet thick at 40 feet below the surface and 8 feet at the surface. A very important speciality in this embankment, and one which would have made it almost perfect if the culvert had been properly constructed, is the employment of peat. A lining of this substance, 3 feet thick, was brought up on the

inside of the puddle, and also on the face of the slope, well worked and trodden together in an almost dry state. This formed an excellent protection to the puddle, expanding as it contracted, and preventing cracks and settlements; whilst on the face of the slope it prevents the water getting into the embankment. A course of gravel is laid, about 18 inches thick, over the peat, on the slope of the embankment, and above that stone-pitching 2 feet thick. The slope on the inside of the embankment is for 20 feet below the top of the bank 2½ to 1, and below that 3 to 1; on the outside, 2 to 1 for 20 feet, and 2½ to 1 for the remainder. The embankment is 12 feet wide at top, and 5 feet above the top water level. A culvert is constructed in the solid ground under the embankment to discharge the water; it is divided in the centre by a solid piece of masonry, through which three 18-inch pipes pass; one of these is closed up, and the other two are sufficient to vent more water than the Muddock River will bring down to the Bann. As the inner half of this culvert is open to the reservoir, it is always filled with water; the outer one contains the two pipes, which are carried to the outside of the embankment, where the valves are placed. The side walls of the culverts are formed in two courses, the lower 21 and the upper 18 inches thick; the inverted arch is 14 inches at the centre, and the arch 15 inches, built of granite ashlar, intended to be square jointed through, and bedded to the different radii, but unfortunately not so carried out. The central division is 5 feet thick, of square ashlar. The inner culvert is laid upon a bed of concrete 18 inches thick, and was intended to have been surrounded by puddle 12 inches thick, the excavation being made just sufficient for this purpose. The superintendent, however, without Mr. Bateman's concurrence, altered this plan, and injudiciously placed a quantity of rubble backing behind the side walls, and then surrounded the whole by the clay which should

have been close to the solid masonry; this rubble backing, to complete the mischief, he carried on past the solid masonry, and through the centre puddle to the outside of the bank from the inside of the reservoir. When the mortar gave way, which it did under a pressure of 12 feet of water, for reasons to be hereafter mentioned, the water leaked through the joints and passed through the rubble backing to the outside culvert. As no water lime could then be obtained in the neighbourhood, Mr. Bateman, unwilling to incur the expense of Roman cement for all the masonry, endeavoured to make hydraulic mortar according to the instructions of M. Vicat, just then published. Although at first the experiment seemed successful, yet, when the pressure came on the masonry, the mortar softened and spewed out. He therefore found it necessary to pick out the joints and caulk them well with oakum to within 2 or 3 inches of the face, and fill the remainder up with Roman cement. The backing also was taken out for a short distance from the back of the breast wall of the forebay, and pounded clay was put in its place and made to surround the tunnel, closely meeting the concrete at bottom and uniting firmly with the puddle round the backing, so as to prevent the water from the end entering the backing. These repairs were made in 1839, and left only a slight leakage. In November, 1841, the tunnel was again examined, and some more joints found to have given away; these also were caulked and pointed with cement, and in consequence the leakage was almost stopped. Since that time the leakage continued to a moderate extent, and the joints of the tunnel were several times examined and repointed, always with the result of a temporary diminution of the leakage, until about three or four years ago, when there was a considerable subsidence in the pavement close to the breast wall of the forebay; in fact, just right above that part of the culvert where the backing had been removed and pounded clay substituted. The

Directors gave directions that the pavement should be made up again, and that some more cementing of joints should be carried out in the tunnel and wing-walls, so as to diminish the leakage. By the year 1867 the leakage had increased so much as to give rise to serious apprehensions; the water was spouting in large quantities from four or five joints in the outer culvert, and formed altogether, when there was 21 feet of water in the reservoir, a stream 3 inches deep passing over a board 2 feet long. The pavement at the old place behind the breast wall of the forebay was found to have sunk again, when the water had fallen low enough to leave it exposed, and a rapid stream of water was running into it. The Directors, after having several communications with Mr. Bateman, got him to visit the reservoir on the 17th October, 1867. He reported on the whole matter, described the origin of the leak, and recommended, as the only effectual means of putting an end to it, that the embankment should be cut open in the centre, down to the culvert; the rubble backing and any soft or loose material existing there taken out, and that a perfectly water-tight wall should be erected on each side of the puddle trench, closely united to the existing masonry, and sunk down below the invert to the retentive ground, in which the bottom of the puddle trench was originally placed. As this was so large an undertaking, and it was then so late in the season, he recommended that in the meantime the reservoir should be emptied, all open joints in the inner culvert caulked and cemented, and the ground opened where the sinking had taken place behind the forebay walls down to the very bottom of the foundations, and re-filled with good clay worked into puddle. He also recommended that a few stones of the invert of the inner culvert should be removed, and the concrete beneath examined, and if found defective a length of 3 or 4 feet of the culvert should be cut open, the defective concrete removed and re-filled by

fresh concrete. If these suggestions were carried out he considered that the reservoir might be more than half filled during the coming winter, and the larger repairs carried out in the following autumn. About the beginning of November the Directors asked me to direct the execution of these repairs, and, if possible, to stop the leakage without having to resort to such an expensive proceeding as the cutting out and replacing of the centre of the embankment. I accordingly visited the reservoir on the 8th November, and found the workmen had cleared out the inner culvert for examination, and removed the rubble pitching on the one side and partly round the end of the forebay. The Roman cement on the inside culvert was generally soft, and there existed one or two small opens in the joints. In the walls of the forebay several opens were visible, through which water had passed and was then trickling back, and there were evident signs of the water having passed into the work close to the wing-wall. I directed the men to follow the fissures in order that the course of the water might be known. A stone was broken in the invert and water came gushing out, showing that the mason work was open behind the pointing and above the cement. Some of the Directors were of opinion that it would be sufficient to open and remove the bank around the forebay of the culvert 3 or 4 feet wide and about 4 feet deep, and fill the space up again with puddle and peat; but as the bank was defective around the west wing-wall and breast of the forebay quite down to the foundations, I found it was necessary to remove it to that extent, and lay bare nearly 6 feet of the culvert. The source of the late heavy leakage and settlement in the bank was then easily seen to be the failure of the puddle or pounded clay which had been put in when the backing was removed in 1840, for the following reasons: The wing-wall, instead of being closely jointed to the back, was quite open, and overhung, consequently, when the clay

or earth, which was of a very inferior description, was put in behind the wall and around the culvert, and afterwards contracted and settled down, it left a space for the water to enter and run down into the mason work of the culvert. The masonry of the culvert itself was defective, as the arch stones were not close jointed to the back and dressed there to the circle, but rough and open. I was very desirous to adopt Mr. Bateman's recommendation to cut open part of the culvert, so that the cross-wall should be regularly commenced on the solid ground; and as it was brought up, properly incorporated with the old work; some of the Directors, however, objected to the disturbing of the old masonry, under the apprehension that it would induce a settlement in the embankment, at the deep cut in which the men were employed; and as the season was far advanced, it was arranged to resort to the more expeditious plan of undermining the culvert and making up the cross-wall underneath and around it. Although the other would have been much more complete, and as the embankment as well as the masonry, after thirty years' existence, must be very solid, there would be little danger in the operation, especially as there was a means of staying up the sides of the cut. It need not have taken much more time, provided a good foundation had been early obtained; and in case it was determined at some future time to prevent all trouble from the joints in the culvert, the metal pipes might be extended as far back as the cross-wall, where the tunnel would be closed by a solid wall or plug of firebrick and cement, expansion joints being provided for the additional length of pipe. The old concrete was found to be fresh and good, a vacant space, however, where the water had free passage, was found to exist between it and the invert. Beneath the concrete the foundation was bad; for although firm where free from water, in this wet place it got through the working into

a state resembling running sand, and a bar was easily sunk to the head in it. Some large flag stones were procured, laid down firmly, and upon them a firebrick and cement wall was erected. The wall, Fig. 4 and 5, was commenced three feet thick, extended on both sides into the solid bank, and wedged up firmly under the culvert. As it was being brought up around the culvert, grouting made of Portland cement and sand and cinders, was poured in and allowed to fill all the crevices in the ashlar of the culvert. No good puddle could be got on the Reservoir Company's ground, so it had to be drawn half a mile; and as 200 or 300 loads of it were required, and the owner had to be paid a high price, the expense was proportionably great. It was of very good quality, however, and was rammed very firmly against the wall, and all brought up together. I was most particular about this, as a settlement of the new from the old firm work was particularly to be dreaded. As an additional security, I procured several stacks of dry turf, had them cut up into small pieces, and pounded into the puddle wherever it was at all springy, thereby securing great firmness, as turf expands very much with water, and makes up for the shrinkage of the puddle. Before using it I made some experiments in my laboratory on this point, and found that a dry turf of good quality expanded 20 per cent. under water, absorbed 55 per cent., and increased 241 per cent in weight. Dry peat would, under like circumstances, even expand much more, as the former is expanded by water in the making and dried in that state. Peat is therefore invaluable as a protection to puddle. The wall of firebrick and cement was reduced to a thickness of three bricks in length about the middle of the culvert, and brought up to a height of about 2 feet above the top of the arch. The back of the western wing-wall was levelled and jointed with Portland cement, and the space opened behind it filled to a certain height with puddle brought up together

with, and in the same manner as, the puddle round the brick wing-wall and culvert, leaving sufficient space on the top for the peat, gravel, and pitching. The bank was firm and good behind the eastern wing-wall, so it was not disturbed. A slight run of water at the corner of the forebay, on the east side of the culvert, continued all the time the place was open, supposed to be either a spring in the bank or the water which had got into the bank from the leakage returning slowly. The peat for the face of the bank was got out of the lake, which abounds in this substance, but as it was rather wet, some of the dry turf was cut up and mixed with it—all being well wrought together so as to be water-tight. I tried both the puddle, the old peat, and the new peat, as the work went on, by hollowing out in them receptacles for water, which proved by suffering no apparent diminution, that the bank, in the absence of pressure at least, was water-tight. Over the peat, gravel was carefully laid, and then the pitching made up and united with the old work, but raised a little higher so as to allow for some subsidence. In putting in the new material it was carefully stepped back on and united with the old. All the joints which were observed to be deficient in the forebay were scraped out and well pointed with Portland cement. In the inner culvert a stone was removed from the invert near the pipe end and all the water baled out from time to time. The loose joints in the sides and bottom were then cleaned out, beginning at the forebay, and surrounded by little clay dams into which Portland cement mixed up with pounded cinders and reduced to a thin grout was poured as long as the joints received it. This was done with every joint until the recess where the stone was out was reached, and the grout flowed out there. The same thing was done from the pipe end to the recess, which was then made up with fire-brick and cement, and thus the entire invert and part of the sides were made good. It

was impossible thus to fill the top arch and upper parts of the sides, so they were merely pointed in front wherever any loose joints were observed. When all these places were closed, although the reservoir was still empty, a slight stream, such as a $\frac{5}{8}$-inch pipe would vent without an appreciable head, was observed to flow down between the pipes in the outer culvert. This probably is either a spring, as the culvert is under the level of the original ground, and in testing the water by Clarke's test, I found it harder than that of the lake, or it may be water lodged in the bank from the old leak. The pounded and riddled cinders were used with the Portland cement instead of sand for grouting, as the latter, from its greater weight, generally sinks to the bottom. Altogether about 60 barrels of the Nine Elms Portland cement were used, and 7,500 Coal Island fire-brick, the carriage of these articles was a very heavy item, as Lough Island Reavy is so inaccessible. The whole cost was about £300; and if, as it is now pretty certain, the necessity for cutting out the centre of the bank will be obviated, a large saving will be effected; for although the latter plan is most to be recommended from its completeness, yet it would cost a great deal, not only for work done, but also from the loss of the water to the mills for one season.

James Byrne, caretaker of the reservoir, superintended the labourers, and I obtained valuable assistance from Mr. Frazer, engineer and manager of the Gilford Mills, who directed the excavations and mason-work, and also from some of the Directors, who often visited the works with me. The work was so successful that the Directors' report to the shareholders, dated 31st December, 1867, just after it was finished, states: "No leakage now appears, although the water in the Lough is three feet higher than the top of the tunnel. Your Directors hope and believe that the work is now more perfect than it has been since its first construction;" and the report

for 31st December, 1868, states: "The repairs executed last year at Lough Island Reavy tunnel withstood, in May last, a pressure of 26 feet (being the highest water of the year), previous to running off, and did not exhibit anything more than a slight leakage—so slight, indeed, that your Directors did not consider it necessary to make any search after it this year. The pressure is now 34 feet, being within 4½ feet of top water, and no appearance of increased leakage. The amount at present passing out between the pipes at the mouth of the outer culvert forms a stream ¾ inch deep over a crest 3 inches long, and may be regarded as nothing compared with the amount before the repairs, viz., 3 inches deep over a 2 feet crest. Deducting, too, the amount due to springs, there results a very small leakage, such as may be entirely prevented by resorting to the old method of caulking and pointing all the imperfect joints in the inner culvert when the reservoir is again empty."

The repairs were about two months in being carried out, and from the inaccessibility of Lough Island Reavy many difficulties were experienced in procuring men and material. Also from the desire of some of the Directors to curtail expenditure, and the hurry to let the water into the reservoir, many precautions I was anxious should be taken were foregone. The success, therefore, of the work rather exceeded my anticipations.

[Read 10th March, 1869.]

DESCRIPTION *of the* IRON LATTICE GIRDER ROAD BRIDGE, *recently erected over the* RIVER BOYNE, *at the* OBELISK.—By WILLIAM G. STRYPE, Associate.

THE extensive and successful application of the lattice girder system of bridge of late years, so much used in railway

construction, showing that both durability and economy can be combined by the adoption of this system, doubtless has led our County Engineers to turn their attention to the desirability of applying lattice work bridges to supersede the temporary wooden bridges, or the more stable works of stone hitherto generally adopted.

There are many points in favour of lattice girders, as compared with the solid plate web, which invariably lead us to reject the latter in preference to the former. Among other advantages inherent upon lattice girders, is the certainty of the strains proceeding in the various channels allotted to them; the economy of material in the web; the small resistance offered to wind; great facility for painting and repairs; and not the least favourable feature is the elegant and light appearance of the whole when completed.

In all cases of lattice bridges used for public traffic, a broad distinction must be drawn between them and similar works executed for the support of the permanent way and rolling stock in connexion with railways; in the latter case the load is always kept in a fixed direction, definite rules can be laid down for its working, and all abnormal strains are brought to a minimum: whereas with public bridges, especially county ones, no such regulations can be made; here we have no immunity from blows being imparted to the bars by passing loads coming in contact with them. In the one case we have known and fixed loads, and in the other, loads ever varying both in intensity and also in direction; for although long lattice compression bars, if properly constructed, require but slight wind bracing when resisting normal strains, yet when the bars are practically converted into girders, subject to impact of an incalculable nature, the construction of the parts must necessarily be varied accordingly.

The bridge about to be described is of the lattice girder type, and has been constructed to replace the former wooden

structure, which had been carried away by the action of ice, in time of floods, in the early part of the year 1867, some of the timbers having become decayed. The wooden bridge, together with the stone abutments, was erected over the River Boyne, close to the Obelisk, in the year 1856, at a cost of about £1,000.

The new bridge has been erected upon the same site as the old one, the original abutments, as far as available, being used again. The abutment on the south side was merely taken down to the corbel course and rebuilt. The northern, or the abutment on the Obelisk side, was taken down to the level of the shore, and produced 28 feet into the river; leaving a clear span, for the new bridge, of 120 feet. The general outline of the bridge may be gathered from the elevation and plan in Plate X, Figs. 1 and 2; the section Fig. 3, and also from the details in Plate X. The cost of the new bridge, including foundation and stone work, was £2,540.

Messrs. J. Neville, T. Searanke, and A. Tate, Civil Engineers, acted in the interest of the two connected counties, Meath and Louth, as engineers for the work; Messrs. Thomas Grendon and Co., of Drogheda, being the contractors for the whole of the work, including some slight alteration in the level of the approaching roadway on the Co. Louth side.

The foundation of the new abutment on the north side was carried down, immediately under the girders, to 6 feet below the bed of the river at the side, and was built upon a concrete bed 5 feet thick, with a good gravel subsoil. Upon this was raised the masonry of rock ashlar up to the corbel course, cut stone work being introduced from this level upwards.

As mentioned already, the old abutment on the south side was made available for the new bridge, after removing the old stone work down to the corbel course, and rebuilding with cut stone work, similar to that on the north side.

The bearing plate stones, at the ends of the girders, are

4 feet square by 1 foot 6 inches thick, and are laid upon, in each abutment, two binding beams of rolled iron, which run right across the heart of the stone work, forming very efficient binders. The rolled beams weighed $52\frac{1}{2}$ lbs. per foot run, were 12 inches deep, with flanges $5\frac{1}{4}$ inches wide, and $\frac{3}{4}$ inch average thickness.

Throughout the whole of the stone work, hoop-iron, with well oxydized surfaces, was extensively used to increase the bond.

To protect the foot of the abutments from the effects of the strong currents which, in time of floods, take place in the river at the site of the bridge, a large quantity of loose stones was deposited at the foot of each abutment. This provision was rendered more necessary from the fact that the bridge crosses the river immediately below a very sharp bend.

The total length of the main girders is 128 feet, that of the latticing 125 feet, and the clear span between the abutments 120 feet. A land bearing of 4 feet, at each end of the girders, was thus provided. The depth between the flange plates is 10 feet 8 inches, equal to $\frac{1}{12}$ the total span, and the width between them 16 feet—the clear width of roadway, or the width between the inside planes of lattice bars, being 16 feet 8 inches.

Sufficient strength is provided in the main girders to sustain a total load of 3 cwt. per superficial foot, when the iron in tension is strained up to 5 tons per effective square inch of section, or 4 tons per inch, including rivet holes, for compression strains.

The cross beams have sufficient strength to support a load of 5 cwt. per superficial foot, the additional strength being given to meet the contingency of a very heavy load resting on each beam in succession; the imposed strains on the iron being as before.

The total load on the main girders, with this data, is 300

tons or 150 tons on each, giving strains in the flanges of 220 tons. The flange plates are 2 feet wide by $1\frac{1}{4}$ inches thick in the centre, and are made up of four layers, viz., 128 feet, or the whole length of the girders, $\frac{3}{8}$ inch thick; 90 feet $\frac{3}{8}$ inch thick; 69 feet $\frac{1}{4}$ inch thick; and 48 feet $\frac{1}{4}$ inch thick. In addition to this there are four lines of angle iron 6 inches $\times$ 4 $\times$ $\frac{5}{8}$. The arrangement of the layers of plates, joints, and connexions, is shown on Fig. 7, where it will be seen that the outer plates, at the points A, B, C, and A′, B′, C′, are produced beyond the joints to form covers. At the points D, E, D′, E′, cover plates are provided; in addition to this, at each of the joints, extra cover plates are placed underneath between the two inner lines of longitudinal angle irons, additional rivets are provided at the joints, placed between the middle continuous lines of holes, thereby adding rivet strength to the joints, and also by the under covers localizing the direction of the strains in the flanges more to the centre of gravity of the material.

Fig. 7 is also a diagram of strains in the web, and also gives the dimensions of the bars for a single plane of latticing.

It will readily be seen from the arrangement of the flange rivets, Fig. 2, that the additional rivets at the joints of the plates do not in any way weaken the flanges by reducing the effective section, since from the nature of their distribution and the cover plates being carried beyond them, the advantage of lozenge riveting is obtained.

The joints of the longitudinal angle irons are arranged to occur only between the intersections of the lattice bars, breaking joints with each other and with the flange plate joints, and were formed of round-backed angle covers $\frac{1}{2}$-inch thick, and solid bars, 6 inches $\times$ 1, let in between the adjacent pairs.

Two planes of latticing are provided for each girder, the ends of the lattice bars being riveted between a pair of the longitudinal angle irons on the flanges. The triangulation is

sextuple; the cross beams rest upon cast-iron chairs at the apexes of the triangles.

The compression lattice bars towards the end of the girders are of channel iron; those near the centre of angle iron, and which were carried past the centre, so that the meeting angle bars crossed and were woven upon each other about the centre. To enable the flat or the sides in the same plane as the latticing, to be closely brought together, pieces of the standing-up webs of the angle bars were removed.

Upon all of the compression bars, whether channel or angle iron, wind bracing $1\frac{1}{2}$ inches $\times$ $\frac{1}{4}$, was introduced; thereby rendering all the compression stiff against lateral strains.

The end pillars are made box form in section, the front members being lattice work to allow of the inside being readily painted.

The cast-iron land bearing plates, are 2 feet 9 inches $\times$ 2 feet 6 inches, Figs. 4, 5, 6. The bearing plate stones are sunk 1 inch deep for the plates, which are let into the stones $\frac{1}{2}$-inch, the $\frac{1}{2}$-inch space being filled up with molten lead after the plates had been carefully levelled and adjusted. The expansion rollers are 4 inches diameter by 2 feet long, and are four in number for each girder; the rollers are turned and the plates planed. The cross beams are constructed of $\frac{5}{16}$ inch web plates, 3 inches $\times$ 3 $\times$ $\frac{1}{2}$ double angle iron flanges, and are 17 inches deep in the centre, and 12 inches in the ends, the curve in the beams giving the required convex form to the surface of the roadway. The beams are 35 in number, and are spaced 3 feet $5\frac{2}{3}$ inches apart centres in the plane of the bridge.

The roadway is supported from the cross beams with Mallet's buckled plates, weighing $67\frac{1}{2}$lbs. per square yard, and have a versine of $2\frac{1}{2}$ inches; four plates are laid in the width of the bridge.

In forming the roadway a layer of wooden chips, sand, and

coal tar was first laid, brought up a little over the level of the crown of the buckled plates, upon which was laid asphalte 8 inches deep, consisting of broken stones, sand, and coal tar. This road-covering is retained laterally by wrought-iron plates 12 inches wide by ½ inch thick.

It will be noticed that the main girders are not in any way trussed or connected together, except by the road beams and buckled plates—and it has been very well ascertained that any such bracing was not at all requisite, which clearly was shown by the absence of vibration in the bridge during the repeated attacks of strong winds so much encountered of late.

WEIGHT OF MATERIALS			
	Actual Weight	Theoretical Weight	Per centage lost
Top flange, compression, -	382 cwt.	302 cwt.	26 per cent.
Bottom do., tension, - -	382 „	242 „	58 „
End pillars, compression, -	41 „	12 „	242 „
Latticing, compression, -	152 „	75 „	114 „
Do., tension, - -	114 „	71 „	60 „
Totals for girders proper,	1,071 cwt.	702 cwt.	52½ per cent.
Hand rail bars, - -	26 „		
35 Road beams, - -	315 „		
70 Cast-iron chairs, - -	44 „		
Buckled plates and retaining plates, - - -	210 „		
Asphalte, - - -	754 „		
Total weight of Bridge,	2,420 cwt.	= 121 tons.	

The above table of weights gives the actual weight of material, theoretical weight, and the per centage of material practically required over the theoretical quantity, or the loss of iron due to rivets, holes, cover plates, and stiffeners for the

main girders. The weights of the other portions of the bridge are also given. The theoretical quantities in the table are calculated to provide sufficient material in the parts to allow of its being only strained to 5 tons per inch for tension and 4 tons for compression. It will be seen from the table that the top and bottom flanges respectively, compression and tension members are equal in weight; the top flange, theoretically, requires more material than the bottom in the proportion of 5 to 4, but as the effect of rivet holes is not considered as reducing the area of the top flange, the loss of iron arising from that reduction only affecting the tension flange and bars, accounts for the similarity in the ultimate weights. The same reasoning would explain the difference in the per centage of loss in the two flanges. The per centage of loss in the end pillars is high, 242 per cent., owing to the necessity of rigidly combining the top and bottom flanges at their ends by those members. In the web the quantity of material required fo giving lateral stiffness to the compression bars causes the average loss in that part to be 114 per cent.; at the end of the girders the loss is 26 per cent., whilst at the centre it increases to 270 per cent., this is quite reconcilable, when we consider the small theoretical quantity of material requisite at the centre of the web, and the liberal allowances which have to be added to give lateral stiffness. The average loss of material in the tension web bars is 60 per cent., the maximum 120 per cent., and the minimum 45 per cent.; the loss of iron in the tension bars is only that due to rivet holes, the variation in per centage of loss arising from the fact of the diameter of the rivets and the thickness of the bars being constant. The total loss of iron in the girders is 52½ per cent.

The weight of the main girders is 8·5 cwt., the roadway 10·8 cwt., forming a total of 19·3 cwt. per foot run. The weight per square foot of roadway surface is ·52 cwt. for the

main girders, and ·65 cwt. for the roadway, the total being 1·17 cwt. per square foot. Since the strength of the girders was calculated to sustain a total load of 3 cwt. per square foot, by adding the greatest load—say dense crowds—at 1·03 cwt. per square foot, to 1·17 cwt., the weight of the bridge, we have 2·20 cwt. for the maximum load, which, from the calculated load of 3 cwt. leaves ·8 cwt. of surplus strength to allow for deterioration of the iron in the various sections. The cross bars, as will be gathered from the context, have a greater surplus than this.

After the masonry had been completed and the bearing plates set in position, but before the terminal piers were built, the main girders were brought, in a finished state, up the river about four miles, from Messrs. Grendon and Co.'s Works, to the site of the bridge, upon a pair of pontoons. In taking the girders from the shore the services of the 30 ton shears erected on the wharf at the works were made available. Two ponts, each capable of floating thirty tons weight, being provided, were prepared with a line of levelled blocks on the decks to receive the girders.

The main girders, each weighing in round numbers 28½ tons, were removed separately to the site of the bridge as follows:—each girder having been brought to the edge of the river, was, with the aid of the shears, run out across the river and placed upon the levelled deck of one of the ponts. When well shored up from the pont, the girder was further pushed out into the river, and the near end caught up by the shears and placed on the deck of the second pont. The girder being now afloat, resting upon the ponts, the longitudinal centre lines of all being in the same direction, was towed up the river to the site of the bridge, and at high water placed upon timber platforms prepared for it close to the abutments. It may be mentioned that the river Boyne is effected by tidal influence for some distance up beyond the site of the bridge;

at the site the rise and fall of the water varies from three to five feet between neap and spring tides. As the tide receded, and when the girder rested on the shore platforms, the ponts were removed and again replaced to a position at right angles to the longitudinal axis of the girder, and consequently with their centre lines in the direction of the river. This was necessary both for lessening the pressure of the current upon the ponts, and to give greater stability to the whole floating structure, as the centre of gravity was elevated, by repeated lifts above the ponts. The work of raising the girders by the rising tide was assisted by partially filling the ponts with water previous to wedging in the blocks at the lowest point of the tide, and pumping out the water as the tide rose.

The girders were thus raised eleven feet, and when at the required height were drawn sideways, and dropped into their seats on the abutments, the cross beams, road plates, &c., being readily fixed in their respective positions afterwards.

According to the terms of the specification, the bridge was to have been tested with a total distributed load of 350 tons. As several of the interested persons using the bridge objected to submit to the inconvenience of having the thoroughfare blocked up with a test load, this idea was abandoned, and the bridge merely loaded with a number of heavy cattle, equivalent to a distributed weight of 60 tons, which, with the weight of the bridge, 120 tons, equals a total test load of 180 tons, or but about one-half the specified test. Although this was smaller than desirable, yet the probability is that a greater weight will never be imposed on the work. The cattle driven on, gave a pretty satisfactory test to prove the lateral stiffness of the web, for, in running them on the roadway of the bridge, they were well packed in by driving them up to the centre from each end, resulting, of course, in a considerable lateral strain applied to the web.

There is a point of detail with regard to the arrangement

of the rivet holes for uniting together the different layers of plates and angle irons, also the connecting together of the ends of plates or bars in girder flanges in such bridges as the one described, to which attention is invited. The three Figs., 8, 9, 10, will illustrate the subject.

Since it is of great importance to reduce to a minimum the loss of sectional area caused by having rivet holes at right angles to the direction of the flanges in iron girders, the longitudinal lines of rivet holes have, in the best practice, been arranged in a zig-zag system to diminish the loss of iron. As it is desirable to have rivets pitched close enough to perfectly "stitch" the plates, a pitch will be arrived at for a given size of flange, which will, as dictated by experience, be the most suitable. In the case of girders for such a bridge as that described, where four lines of angle iron and a number of flange plates have to be united, say, four lines of rivets 1 inch diameter, at 6 inches pitch, are adopted for the purpose. This can be accomplished by either of the methods shown. It is obvious, by inspection of the Figs., that the lines of fracture of the plates, with the holes arranged as shown, will be as marked, and will depend in each case upon the upper or the lower lines of the fracture having the least effective sectional area. The following calculation will show the amount of material lost in the different arrangements:—

Let the plates be 24 inches wide, and 1 inch thick, the effective area will consequently be 24 square inches.

In Fig. 8 the plate is diminished in section by four holes, the effective section will consequently be $(24 - 4) = 20$ inches, and $\frac{1}{6}$ of the total plate area is lost.

In Fig. 9 the breaking line will be either as shown on the upper, or in the direction marked on the lower side of the Fig., depending on which has the most effective area. The area of the upper fracture is $(24 - 2) \times 1 = 22$ inches; that of the lower $[2\,(2 + 5 + \sqrt{5^2 + 3^2}) - 4] \times 1 = 21{\cdot}66$ inches, so

that the weaker line is in the later direction, and $\frac{1}{10 \cdot 26}$ of the total plate area is lost.

In Fig. 10 the breaking point is either as shown by the upper or lower line of fracture. The effective area of the upper line is, as before, 22 inches, and the lower $[2(2 + \sqrt{5^2 + 3^2}) + \sqrt{10^2 + 3^2} - 4] \times 1 = 22 \cdot 1$ inches; the plate is thus slightly stronger on the line of lower fracture, and the loss of total area $\frac{1}{12}$.

The last arrangement has been adopted in the Obelisk Bridge, the pitch of the rivets being as mentioned; their diameter $\frac{7}{8}$ inch.

Although the advantage resulting from this arrangement may be regarded as small, and it may be stated that a similar result could have been attained by slightly increasing the pitch of the rivets in Fig. 9, yet when this modification does effect a saving, and enables the rivets to be placed closer together without in any way interfering with or increasing the workmanship, the matter should merit attention.

[Read 12th May, 1869.]

On Hydraulic Machinery *for obtaining* Small Motive Power.—By William Anderson, Ex-President.

Engineers are so much taken up in constructing grand works, and afterwards describing them to assemblies, such as that now addressed, that it almost requires an apology for introducing a paper professing to deal with very small matters. But, as the enjoyments of life spring more from slight causes constantly acting, than from great and exceptional events, so the usefulness of numerous minute domestic contrivances contribute more to our daily comfort than the grand public works of which so much is heard. The city of

Dublin has lately spent an enormous sum of money to secure the priceless boon of a good supply of water, and this Institution has heard and placed on record the manner in which the great work has been carried out; but the benefits of the undertaking are felt over a comparatively small area, so that its history and prospects do not command a very extended interest. The paper brought before the Institution this evening has for its object the description of what may be called domestic water works, and the author hopes that the record of his experience may prove of use to a wide range of country, in emboldening the members to utilize very low falls, and scanty streams, for the purposes of efficient water supply.

The author's attention was first directed to the subject about two years ago, on being consulted by a gentleman in Dorsetshire, who wished to obtain water for his garden from the river Stour, which flowed at the bottom of it. The fall available was only three inches, and it was desired to raise five gallons per minute 26 feet, representing only 0·04 horse power. An undershot water wheel with curved buckets, constructed on General Poncelet's principles, was made, and set to work with complete success. The wheel is 5 feet in diameter, 2′ 6″ wide, working in a cast-iron case, the bottom of which is formed to fit closely to the periphery of the wheel for a space greater than the pitch of the buckets. Upon one end of the axle of the wheel is forged a crank plate, containing four holes at different distances from the centre, to receive a crank pin which works a pair of 2¼″ pumps, secured to the iron framing of the wheel race. The arrangement is similar to that represented in Plate II., Figs. 1 and 2, which, however, are the drawings of a wheel made subsequently for Earl Manvers, for a higher fall. The crank pin turns in a cast-iron block, sliding in a slot formed by the junction of the two cross heads on the ends of the pump plungers. By this

arrangement the pumps are brought into a very small compass, and can be fitted up self-contained with the wheel case.

The wheel itself is keyed on a wrought-iron axle, and consists of a pair of cast-iron sides, with suitably disposed flanges to which sheet iron buckets are bolted. The pumps are of the ordinary description, having their barrels bored out to serve as guides to the plungers, which are provided with double cup leathers. The valves are of the ordinary conical type, disposed in cases at the ends of the barrels, the suction and delivery valve chests of the two pumps being connected respectively by wrought-iron pipes. The success of this wheel soon led to the construction of many others for falls varying from 3 inches to 2 feet, and lifts up to 120 feet with many hundred yards of rising pipe. For these higher falls it was necessary to reduce the depth of the stream or jet entering the wheel, to about 2 inches, which, as no means of varying the power is required for raising a fixed quantity of water, was very simply done, by fitting in a sliding plate between the head race and the wheel, Plate II., Fig. 1, and fixing it by brass set screws, at whatever depth of opening was found to give the proper speed. The Dorsetshire wheel had no such plate, being in fact more properly a stream than a Poncelet wheel. A common wooden shuttle or sluice, Plate II., Fig. 1, working in an iron frame, actuated generally by means of a gun-metal screw and nut, and fixed quite independently of the wheel, serves to stop or start it.

The smallest water-wheel of this class yet made, is represented on Plate II., Figs. 1, 2, 3, and was constructed last summer for Mr. Jackson, a gentleman residing on the bank of the Thames, between Gray's and Tilbury. The water supplying this wheel issues from springs in the chalk, with a fall of between 5 and 10 inches, and finding its way through the marsh drains at low water into the river. The wheel raises $\frac{3}{4}$ gallon per minute, 80 feet high, doing 0·018 horse

power, and supplying a large farm yard, and the owner's house and grounds, a reservoir having been constructed to store the water pumped during the night. The general arrangement in this case is the same as that already described, but the wheel is only 3 feet in diameter, $8\frac{3}{4}''$ wide, and made of $\frac{1}{4}''$ plate iron sides, with the buckets morticed and riveted in, the whole galvanized when quite finished; the pumps are $1\frac{1}{4}''$ diameter, $5''$ stroke, and are made all of gun-metal. The sluice for admitting the water is formed by a wooden gate sliding in a groove cast in the wheel case, so that the amount of water can be varied with the variation of fall, which, in this instance, fluctuates considerably from the difficulty which the tail water finds in getting away at certain times of the year, when the drains become full of vegetation.

It is not the purpose of this paper to describe the mode of setting out and constructing Poncelet wheels; full information on these heads may be found in General Poncelet's "Mémoir sur les roues hydrauliques à aubes courbes meues par dessous," or in General Morin's "Hydraulique." The author will only remark, that extreme care must be taken in dealing with such small powers, to ascertain and allow for every resistance, such as the loss of head in the channels of approach and efflux, as affecting the fall; the resistance of the rising main, as affecting the pressure on the pumps. No experiments have been made to determine the duty done by any of the wheels now at work, but it has been found that an assumed useful effect of 50 per cent., according to which the dimensions have been fixed, has always been justified in practice. For some days after first starting, especially with long rising mains, the wheels fall short of their work, partly from stiffness of the working parts, but chiefly from the lodgment of air in the pipes, but as this works out the wheels settle down to their proper speeds. The general practice is to fix them in vaults covered with a grass mound, or wood cover,

Plate II., Fig. 1, an ordinary street sluice-cock box being fixed, through which the attendant raises or lowers the sluice with a turncock's key. A trap door is provided for access to the wheel, and oil cups on the several parts keep it lubricated for many days.

It is scarcely necessary to point out that the comparatively high speed with which Poncelet wheels revolve, enables them to be applied to the purpose of pumping without the intervention of wheel-work or multiplying gear of any kind, the pumps at the same time remaining of moderate capacity. The proper speed for the periphery of a wheel is half that due to the fall, so that when the latter is only 3 inches, a 5 feet wheel should make eight revolutions per minute, and may be driven at twelve without sensible loss of duty. With a 12″ fall the proper speed is sixteen revolutions, and with 2 feet twenty-two, while a 3 feet wheel with 10 inches fall, will make twenty-four turns per minute. The common contrivance of a crank plate, with several holes for the crank pin, at various distances from the centre, offers a simple and convenient means of varying the power of the wheel according to circumstances.

Where the falls become greater than 3 feet, it becomes convenient to adopt a different arrangement, chiefly with the view to economy of material. Plate II., Figs. 6 and 7 represents a Poncelet water wheel and pumps, erected last year at Terling in Essex, a village which the members may recollect was devastated by fever a couple of years ago, in consequence of defective sanitary arrangements. The fall in this case is 5′ 9″, the wheel only 7 feet diameter, and 12½ inches wide. In the ratio between the fall and the diameter of the wheel, the author believes he has far surpassed anything that has been attempted hitherto, the usual rule being to make the diameter at least twice as great as the fall; but the result quite justified the experiment, and there does not appear to be any reason

in theory against reducing the diameter of the wheel from the proportions recommended by Poncelet, provided the buckets are deep enough to prevent the jet of water rising over their inner edges, which result is obtained if the depth of bucket is made not less than a quarter of the fall, because the velocity of the periphery of the wheel being half that of the impinging jet, the relative velocity of the bucket and the water is roughly half that due to the fall, and hence the stream of water, setting friction aside, would mount the bucket to one-fourth the height of the fall. The shrouds and buckets of the Terling wheel, with the view to great durability, are made of cast-iron in one piece, with cast-iron arms bolted on to either side, the whole being keyed upon the shaft of a cast-iron three-throw crank, actuating a set of horizontal pumps 4½″ diameter, 9″ stroke.

The water is admitted by a 12″ square pipe, bell mouthed at its upper end, and terminating at the lower in a jet piece comprising a portion of the race fitting the wheel for a greater space than that between two buckets, and a wooden shuttle or sluice working against a planed surface, and actuated by a gun metal screw and nut through a pair of bevel wheels, by a hand wheel from the platform covering the wheel pit. By this arrangement an important feature in Poncelet wheels is secured, namely, making the length of the jet between the orifice and wheel as small as possible. The wheel makes 26 revolutions per minute, and the pumps deliver forty gallons in the same time, to a height of 80 feet, representing barely one horse power. As an illustration of the compactness attained by this system, it may be mentioned that the present wheel and pumps fit into the wheel race of an old breast wheel that was removed to make room for them about 18 inches of the wheel cover only appearing above the old side walls.

When the fall exceeds 6 feet, recourse must be had to turbines, but these, as the fall increases to about 20 feet,

become inconveniently small, and revolve at a destructive rate. Hydraulic engines of a very simple construction are then adopted, and as an example may be cited a combined hydraulic engine and pumps, recently made for the Duke of Buckingham. The fall in this case is 17′ 6″, with only 16 cubic feet of water available per minute, with which it was required to raise five gallons per minute, to a height of 150 feet. The engine consists of a horizontal cylinder 6 inches diameter, 8″ stroke, provided with a common slide valve of exaggerated dimensions as compared with the cylinder, in order to give the necessarily large area of water way. The supply and exhaust pipes are five inches in diameter, the latter dipping down into the tail water, so as to render available the fall below the cylinder. The piston rod is jointed to a forked connecting rod which actuates an ordinary crank, the shaft of which has a 3′ 3″ fly wheel at one end, and a crank plate at the other, by means of which a pair of $2\frac{1}{4}''$ plunger pumps of precisely the same construction as those applied to the 5 feet water wheels, Plate II., Figs. 1 and 2, are actuated. The crank pin, as in the water wheels, may be shifted into four positions, giving 3″, $3\frac{1}{4}''$, $3\frac{1}{2}''$, 4″, stroke, and delivering at 60, 55, 50, and 45 revolutions, five gallons per minute respectively. This, or some similar arrangement, is very important in hydraulic engines, because water being incompressible it cannot be worked expansively, so that a cylinder full of water must be sacrificed for every stroke of the pumps; but by varying the stroke of the latter they can be made to discharge more or less for the same power expended. A similar result is obtained by varying the stroke of the hydraulic cylinder, as no loss arises from the increased clearance at the ends. This may be done either by means of a crank plate or link motion. The plan adopted by the author, however, is the most compact, simple, and cheap. The combined hydraulic engines and pumps run very steadily

at 40 revolutions; but with single cylinders they will not pass their centres with certainty at much less speed, and they will work smoothly up to 100 revolutions. The inlet pipe is provided with an air vessel just at its junction with the cylinder, so as to destroy the motion of the water at the end of each stroke gradually, and without shock. The slide valve is of gun-metal, working against the natural face of the iron cylinder. The greatest enemies to hydraulic machinery of small power are weeds and dead leaves; the only way to escape them is to take the water from favourable spots, and to construct two or three efficient gratings. These for low falls must be very large, and are best made inclined, so as to be easily raked clean.

In conclusion, the author may remark, that the machinery described has all been made repeatedly, and is at work in various parts of England, so that this paper may be regarded as a record of work actually done, and in satisfactory operation.

[Read May 12th, 1869.]

On a Simple Method *of* Surveying *by* Plane Table.

By Colonel Meadows Taylor, C.S.I., C.E., Member.

ABSTRACT.

The object to be attained, is a survey on the principle of the Theodolite, by back sights as well as forward, on the plane table. The only other instrument necessary is a ruler sight with a fine hole, or holes at different altitudes, to suit inequalities in the ground; a brass plate at one end, and a narrow brass frame carrying a perpendicular hair, at the other. The edge of the ruler, which may be divided into a scale of parts, being in an exact line between the sight holes and the hair, so as to avoid any parallax.

There should also be a plummet attached to the socket below the table in which the pintle of the table moves; by this means the exact centre of the table can be placed precisely over the bench mark, or a cross upon the ground at every new station.

The table should be covered with a sheet of drawing paper securely stretched upon it.

When the table is set up at the first station, the magnetic points can be entered on the sheet, if needs be; but they have no concern with the survey itself.

The survey begins at A. Drive a stout peg into the ground as a bench mark, and set the table by the plummet exactly over it, the plummet touching the top of the peg. Send on a marker with a flag to B; take the sight A B, with the ruler sight, and rule the line on the paper; take up the table and measure the distance from A to B; prick it off by the scale determined upon, and make a dot for station B; drive another peg *between* the feet of the marker where his heels meet, which will represent the position of his flag; this will serve as a second bench mark.

Then set the table on station B, as was done at A; lay the ruler sight on the line B A, and turn the table till the flag at A is exactly covered by the hair. Clamp the table tightly, and examine the sight *after it is clamped*, to be secure against error. Send on the marker to C; take the sight B C, rule the line, and prick off distance as before. Any side offsets can be measured as the surveyor goes forward, and marked at once on the paper. At station C, take back sight C B, and clamp the table as before. Then set the sight upon station A; if the work is right, the pole or flag left at A will be covered by the hair. If they do not agree, an error must have occurred, and must be rectified.

In the same manner take the sight C D; and at D, having set the sight on C, A should correspond. Return to A,

clamp the table on D, and if the work is right, the flags at each station will be covered by the hair sight in succession.

There are now three proved checks by sight; but as a further and more exact proof that the triangles A D C, and A B C are correct, measure the base A C on a right line from A to C; then wherever you find it on the line, say E, take the perpendicular E D. If the distance from A to E, and if the perpendicular E D correspond on the ground, and on the paper, and the table clamped at E, give sights agreeing with all other points, the triangle A D C is proved.

In the same manner prove the triangle A C B. There are now two triangles proved by back and front sights, and by the measurements on the ground and on the paper, of their bases and perpendiculars, and they may be accepted as correct. The survey may now proceed in any direction from either of the proved triangles, on exactly the same plan, always working by back and front sights, with check sights on the original bench marks, or other points of triangles, which have been *tested*, as already detailed, by measurements of bases and perpendiculars.

Practice with the plane table will suggest many short methods to accurate results, and the marking off and plotting irregular portions of ground, rivers, &c., by offsets; but I have thought it better to avoid details, and confine myself to elementary principles.

It will depend upon the state of the atmosphere how far flags at original bench marks can be seen with the naked eye; and it need hardly be said that while new ones can always be laid down in extensive surveys, the field work should not go on very far without them.

By these simple methods, native Indian surveyors instructed by me in the use of the plane table, laid down extensive and intricate surveys of village lands, and every field on them, with such correctness, that no perceptible error

was found on test by the Theodolite. No field book is necessary, and the original plotting on the table can be easily copied, if necessary, for a fair draft.

[Read December 8th, 1869.]

RECORD *of* SOME EXPERIMENTS *on* HEATING WATER *and* CONDENSING STEAM *by* TUBULAR *and* DOUBLE-CASED VESSELS. By WILLIAM ANDERSON, Ex-President.

THE paper which it is proposed to bring before the Institution this evening is intended to be merely a record of some experiments which the author had an opportunity of making in the course of business on a subject about which very little accurate information exists, and which is nevertheless one of great practical importance with reference to surface condensation for steam engines, and the heating of liquids by steam through metallic surfaces.

It will probably be the most satisfactory course to describe the experiments and give the results obtained first, and afterwards draw such inferences as may present themselves.

The first experiment was made on the 6th of July 1869, on a tubular water heater, one of four designed by the author, and constructed for St. George's Hospital, London, and represented in Plate XIII., Figs. 1 and 2. It consists of an outer case of $\frac{3}{8}''$ boiler plate $2'\ 7\frac{1}{2}''$ diam. by $5'\ 0''$ high, fitted with $2\frac{1}{2}''$ diam. inlet and outlet pipes (A and B) at its lower and upper ends respectively. The top end of this vessel is closed by a dome, and its lower end has fitted to it a plate containing thirty-seven $2''$ tubes $4'\ 6''$ long, terminating in a similar smaller tube plate inside the upper end, each set of tube ends being connected by a dished cover, bolted on and forming thus steam spaces embracing the ends of the tubes. Each cover and its tube plate are further connected together by screwed stays after the

manner of the flat surfaces of a locomotive fire box. The lower tube plate extends to the external angle iron forming the lower termination of the outer case of the heater, and is bolted to it by numerous $\frac{5}{8}''$ bolts (C). A 1″ steam pipe (D) is tapped into the lower steam space, and passes to the upper one through the centre tube. A $\frac{3}{4}''$ pipe (E) is also screwed into the lower steam space to carry off the water of condensation, and a small gauge cock (F) is tapped into the lower cover, projecting about one inch through it, for the purpose of ascertaining whether the steam space is clear of water. The heater is intended to be suspended by an eye bolt in its domed upper end, at such a height from the ground that by taking out the bolts (C) the cluster of tubes can be withdrawn when it is desired to clean or repair it. The arrangement of steam pipe (D) insures the complete displacement of the air, which, being heavier than steam, will escape downwards without mixing with the latter, and the water of condensation trickling down the tubes in the same direction, as the current of steam is sure to escape with the greatest rapidity, and leave the heating surfaces unencumbered with water. The heater, which is felted and lagged with wood, is intended to work under a head of 70 or 80 feet of water, and 50 lbs. steam pressure. The four constructed have been in operation for some time with complete success. The weight of the heater is 1,589 lbs., and the heating surface 96 square feet.

The manner of conducting the experiments was as follows: The heater was connected to a cast-iron tank 7′ 7″ square, by a $2\frac{1}{2}''$ pipe coming out of the bottom of the latter to the inlet opening (A) in the outer case of the former, and by another short $2\frac{1}{2}''$ pipe coming from the outlet branch (B) and entering the tank a little below the water level. The steam pipe (D) was connected to a 10 horse portable boiler, a trap (G) being formed close to the heater for catching and letting out any water that might prime over or be condensed in the pipes,

and the outlet (E) for condensed steam was so arranged that it could discharge the water into either of two gauge tanks placed conveniently underneath. A pressure gauge (H) was fixed close to the heater, and thermometers were inserted into the inlet and outlet pipes between the heater and the tank through holes drilled for the purpose. The experiment lasted $4\frac{3}{4}$ hours, during which time, and at intervals of 10 minutes, the temperature of the air, that of the inlet and outlet pipes, condensed water, and surface of water in tank were observed, the quantity of steam condensed noted, and the pressures in boiler and heater ascertained.

The observations in detail are annexed, the general results being that in $4\frac{3}{4}$ hours the contents of the tank, about 2,000 gallons, were raised from 68° to 156°, while $2,476\frac{1}{2}$ lbs. of condensed steam were collected. It is much to be regretted that the boiler was not sufficiently powerful to supply as much steam as the heater could condense, and that the inlet and outlet pipes, which were proportioned for very tall columns of water competent to generate a rapid current, were not large enough to carry off the water as fast as it could be raised to the boiling point—the consequence was that when, by stopping a few minutes to raise a good pressure in the boiler, steam of about 27 lbs. was turned into the heater, the water inside began to boil and issue violently, mixed with steam, out of the outlet pipe. During the whole of the experiment the cock (F) in the lower steam space was kept a little open, and blowing out steam to ensure the space being free from water, and the cock in the water trap (G) of the steam pipe was kept open in the same way. The pressure in the steam pipe where it just entered the heater varied between 5 and 27 lbs., the mean being $11\frac{1}{2}$ lbs.; the pressure in the boiler, owing to deficiency of power, varied between 6 and 64 lbs., the mean being 32·6. A comparison between the units of heat resident in the steam

Experiments Made at Erith, July 6, 1869.

Time	Temperature of					Gallons Condensed Water		Pressure in		Remarks
	Air	Inlet Pipe	Outlet Pipe	Condensed Steam	Top of Tank			Boiler	Heater	
								lbs.	lbs.	
3·10	76°	68°	71°	—	69°	—		57	—	Depth of water in tank at commencement, 5′ 6¾″, and at end 5′ 6¼″.
3·20	,,	,,	172	210°	100	13·8	47·7	41	22	
3·30	,,	,,	195½	205	128	13·8		32	16	
3·40	,,	,,	197	179	148	9·9		18	10	
3·50	,,	,,	183	179	153	10·2		14	8	Indicates change of gauge tanks.
4·0	,,	,,	175	177	154	7.76	32·69	12	8	
4·10	,,	,,	175	172	152	6·90		10	7	
4·20	77	,,	175	166	152	6·03		6	5	
4·30	,,	,,	174	171	152	5·61		9	5	
4·40	,,	,,	150	206	148	0·43		55	24	Stopped to get up pressure 10 minutes.
4·50	,,	,,	211	211	155	5·96		50	27	Pressure kept very steady all the time.
5·0	76	,,	212	209	160	14·23	47·42	39	10	Boiling violently; had to reduce pressure.
5·10	,,	,,	206	198	166	9·48		43	13	
5·20	,,	,,	204	210	173	14·23		35	17	
5·30	,,	,,	203	204	172	9·48		31	11	
5·40	75	,,	200	196	167	9·48	39·22	30	8	
5·50	,,	68¼	200	200	167	9·48		34	11	
6·0	74	68½	203	202	167	10·78		36	11	
6·10	,,	68¾	203½	202	163	9·48		35	11	
6·20	73	69	205½	209	169	9·48	36·64	40	12	
6·30	,,	69	207	204	170	11·64		32	10	
6·40	,,	69½	205	202	173	7·33		26	10	
6·50	,,	70½	204	202	174	8·19		22	8	
7·0	,,	83	198	202	166	—		57	13	Stopped 10 minutes to get up steam.
7·10	72	73	210	208	—	10·78	43·98	64	13	
7·20	,,	77	209	208	175	9·48		50	10	
7·30	71	83	208	208	172	9·06		37	11	
7·40	,,	151	209	206	160	8·19		27	10	7·35 began to stir water in tank.
7·50	,,	155	210	204	158	6·47		3	2	
7·55	,,	156	—	—	156	—		—	—	The tank was kept well stirred till the temperature was equal all over.
			Mean	Mean		247·65			Mean	
			192·3	198°					11·5	

consumed and those appropriated by the water heated will serve as a test of the accuracy of the experiment.

	Units.
2476·5 lbs. water condensed from steam at 32 lbs. per inch (latent heat 986°) - - - -	2,441,829
2476·5 lbs. water cooled from 212° to 198° = 14°	34,671
Total heat units in steam - - -	2,476,500

It is not quite clear whether the whole of the heat contained in the steam as it left the boiler ever reached the heater. Owing to the smallness of the steam pipe there was a considerable difference of pressure between its two ends, and some heat must have been lost for heating purposes by being converted into the work of urging the steam through.

The heat above stated was expended in the following manner:—

	Units.
In heating 19,700 lbs. of water in the cast-iron tank from 68° to 156° - - - -	1,688,720
In warming 1,379 lbs. of water in the heater from 68° to a mean temperature of $\frac{210+156}{2}=183°$	158,585
In evaporating 539 lbs. from the surface of tank at the pressure of the atmosphere (966° latent heat) - - - - - - - - -	520,674
In heating 6,850 lbs. of cast-iron in tank from 68° to 156° (specific heat 0·12983) - - -	78,295
In heating 1,589 lbs. of wrought-iron in heater from 68° to $\frac{156+192}{2}=174°$ (specific heat 0·11379) - - - - - - -	19,201
Total heat units - - - - -	2,465,475

The loss by evaporation from the surface of water in the tank could not be measured directly, owing to the expansion of both tank and water. After the experiment the surface

was found to have sunk half an inch, representing only $14\frac{1}{2}$ gallons, whereas the real loss was nearly 54 gallons. Comparing the two sets of figures it would seem that they agree to within 11,025 units in 2,476,500, or a little less than $\frac{1}{2}$ per cent., which can be accounted for by the loss through radiation and conduction. It will be seen from an examination of the observations that for $2\frac{1}{2}$ hours the temperature in the inlet pipe remained unaltered; that in an hour and 40 minutes more it only rose 15°, while during the last 15 minutes it rose 73°. This result was, of course, to have been expected, because the water, as it was heated, would remain at the top, the thickness of the warm layer increasing as fast as the cold stratum was drawn into the heater. During the last 15 minutes the water was well stirred to bring it all to a uniform temperature before concluding the experiment.

The mean pressure of steam inside the heater is unfortunately a matter of uncertainty; the small cock (F), for ascertaining whether the lower steam space was clear of water, allowed steam to escape, evidently under a very feeble pressure, say $\frac{1}{2}$ lb., while the mean force recorded on the gauge on the steam pipe next the heater was $11\frac{1}{2}$ lbs.—we may, perhaps, therefore assume an average of 6 lbs. The duration of the experiment, deducting 2 periods of 10 minutes during which operations were arrested to allow steam to collect in the boiler, was 4 hours and 20 minutes.

The number of heat units disposed of per hour, therefore, was $\frac{2,476,500}{4{\cdot}33} = 571,940$.

The total heating surface in the apparatus being 96 square feet, the number of units of heat imparted per square foot per hour was $\frac{571,940}{96} = 5,958$.

The mean temperature of the steam in heater was 230°, being that due to 6 lbs. pressure. The mean temperature of

the water passing through the inlet was 78·3°, that of the outlet 192·3°, or an average of 135·3°, making a difference of 94·7°; so that the number of heat units transferred from the steam to the water per square foot per hour, for a difference of one degree of temperature, was $\frac{5,958}{94 \cdot 7} = 63$.

Owing to the insufficient power of the boiler and the smallness of the water pipes, the above duty is probably a good deal below what, under favourable circumstances, may be looked for; indeed, during the half hour between 4·50 and 5·30, when 474 lbs. of steam were condensed in 40 minutes, 66 units of heat per square foot per hour, per difference of 1°, were transferred.

The next set of experiments was made with a wrought-iron double-bottomed boiler (Plate XIII., Figs. 3 and 4), constructed for dissolving animal size for paper making. It is 3′ 5⅞″ diameter, 3′ 6″ deep, with a 2″ steam space (A), extending over the whole bottom, and formed by two ⅜″ boiler plates, the lower one of which is dished to meet the upper, to which it is riveted all round the edges, as well as connected by numerous screwed stays. A ¾″ steam pipe (B) was tapped into the double bottom, and connected to one of the permanent boilers at the Author's works, the water trap used in the previous experiment having been interposed as before to collect primage and water condensed in steam pipe. A ¾″ condensed steam pipe (C) was connected with a gauge tank, a cock (D) was inserted for ascertaining the presence of water in the steam space, and a pressure gauge was connected directly with the steam space, so that the exact pressure there might be ascertained.

The weight of the boiler was 1,169 lbs., and the heating surface 10 square feet.

The experiments were arranged much as in the case of the tubular heater, and are annexed in detail; but, besides

Experiments on a Double-bottomed Animal Size-dissolving Boiler, 3′ 6″ dia., 3′ 6″ deep; weight, 10 cwt. 1 qr. 21 lb.

FIRST EXPERIMENT, JULY 10, 1869.

Time	Temp. in Boiler	Temp. of Condensed Water	Gallons Condensed Water	Pressure of Steam	Remarks
9·50	80°	—	—	—	Temp. of air, 66°. Water in boiler 2′ 3⅛″ deep.
9·55	82	180	1·51	37½	
10·0	91½	203	2·16	40	
10·5	99	194	3·02	41½	
10·10	108	198	3·88	43½	
10·15	117½	208	4·96	44	
10·20	125	206	5·61	44	
10·25	134	205	6·47	43½	
10·30	142	207	7·33	42	
10·35	150	204	7·98	41	
10·40	156	202	8·63	41	
10·45	164	195	9·06	43½	
10·50	171	188	9·49	45½	
10·55	178	204	10·14	47	
11·0	183	207	10·35	50	
11·5	186	206	10·78	50	
11·10	190	206	11·21	50	
11·15	193	207	11·64	47½	
11·20	194	210	12.08	50	
11·25	200	210	13·37	51	
11·30	202	211	14·23	50	
11·35	205	210	15·09	50	
11·40	208	210	15·96	52½	
11·45	210½	209	16·82	53	
11·48	212	210	23·29	52	Depth of water, 2′ 4 7/16″.
	Mean	204·2		46·3	Mean.
12·0	—	—	—	—	Commenced evaporating water 13 7/16″ from top of boiler.
12·5	212	210	1·29	50	
12·10		210	2·59	48	
12·15		210	3·45	47	
12·20		210	4·74	48	
12·25		210	5·61	47½	
12·30		210	6·47	46	
12·35		210	6·90	44½	
12·40		204	7·33	47½	
12·45		211	8·19	49	
12·50		210	8·84	47½	
12·55		210	9·94	45	
1·0		211	10·35	46	Temperature of air, 80°.
1·5		210	11·21	45	Water, 16 1/16 from top of boiler.
	Mean	209·7	13·37	47 lb.	Mean.

ascertaining the amount of work done per hour in heating, that done in evaporating or boiling off was also determined. The first experiment was made on July the 10th, 1869, when 1376·2 lbs. of water were heated from 80° to 212° in 1 hour and 58 minutes by a mean pressure of 46·3 lbs. of steam in the steam space, under the bottom of the boiler, and afterwards 129·6 lbs. of water at 212° were evaporated in one hour and five minutes.

Second Experiment, with about Half the Quantity of Water, July 12, 1869.

Time	Temp. in Boiler	Temp. of Condensed Water	Gallons Condensed Water	Pressure of Steam	Remarks
9·55	70°	—	—	Lbs.	Depth of water in boiler, 12″, 2′ 6⅛″
10·0	83	204	0·86	46	from top of boiler.
10·5	100	208	1·29	50	Temp. of air, 69°.
10·10	119	200	1·51	51	
10·15	140	204	1·73	51	
10·20	160	206	1·94	50	
10·25	172	202	1·94	49	
10·30	180	202	2·16	46½	
10·35	185	210	2·59	45	
10·40	192	210	3·45	48½	
10·45	200	208	4·31	51	
10·50	208	209	5 18	52	
10·55	212	210	7·76	51	12¼″ in boiler; 2′ 5⅞″ from top.
			9·87		
	Mean	206		49·3	Mean.
11·0		—	—	50	
11·5		210	2·16	48	12¼″ in boiler; 2′ 5⅞″ from top.
11·10		210	3·02	45	Commenced evaporating.
11·15		210	3·88	45	
11·20		211	4·53	45	
11·25		210	5·18	47	
11·30		210	6·04	45	
11·35		210	6·90	44	
11·40		210	7·76	50	
11·45		210	8·63	50	
11·50		210	9·06	50	
11·55		210	9·92	48	
12·0		210	11·64	47	9¾″ in boiler; 2′ 8⅜″ from top.
			12·94		
	Mean	210		47·2	Mean.

With 5 lb. pressure only in the steam space there was no violent boiling; no agitation, in fact, whatever.

In reducing these experiments, as in the former case, the loss by evaporation during the heating of the water to the boiling point must be computed from the observed difference in the depth of the water, its known rates of expansion, and that of the wrought iron boiler. In this instance the depth of water had actually increased $\frac{1}{4}''$ at the end of the first portion of the experiment, notwithstanding which 16·55 lbs. of water had been dissipated by evaporation.

The comparison between the number of heat units in the condensed steam collected, and that in the effect produced, stands as follows:—

	Units.
232·9 lbs. water, condensed from steam at 46 lbs. pressure, 294° temp., 981° latent heat, - -	228,474
232·9 lbs. water cooled 212° to 204·2 = 7·8° = -	1,817
Total, - - - - -	230,291

The boiler itself was very unequally heated; the lower part, including the steam space, and weighing about 652 lbs., was probably at the steam temperature of 294°; the upper part, weighing 517 lbs., was about a mean between 212° and 90° or 151°, upon which assumption the units of heat absorbed by the boiler have been calculated.

	Units.
1,376 lbs. of water raised from 80° to 212° = 132° -	181,632
Absorbed in heating boiler, - - - - -	20,056
16·53 lbs. of water evaporated; latent heat, 966°, -	15,987
Total, - - - - -	217,675
Loss, - - - - -	12,616
	230,291

The loss in this case amounted to nearly $5\frac{1}{2}$ per cent., and must be sought chiefly in the difficulty of ascertaining accurately the quantity of water evaporated. The mean temperature of the water was $\frac{80 \times 212}{2} = 146°$, and the difference between that and the temperature of steam 148°.

The number of heat units imparted by the steam per square foot per difference of one degree per hour was

$$\frac{230{,}291^{\text{units}} \times 60^{\text{m}}}{10^{\text{sq}'} \times 118^{\text{m}} \times 148^{\circ}} = 79{\cdot}1$$

During the second part of the experiment, which lasted 65 minutes, 129·6 lbs. of water were evaporated by 133·7 lbs. of condensed steam, the former quantity absorbing 125,194 units, and the latter yielding 131,298, showing a loss of little more than $4\frac{1}{2}$ per cent. The number of heat units yielded per square foot per difference of one degree per hour was $\frac{131{,}293^{\text{units}} \times 60^{\text{m}}}{10^{\text{sq}'} + 65^{\text{m}} \times 82^{\circ}} = 147{\cdot}7$, nearly 87 per cent. more than in the first part of experiment.

A second experiment was made on the 12th July, with less than half the quantity of water, in the same boiler, the general result being that 592·4 lbs. of water were heated from 70° to 212° in one hour, by steam at a mean pressure of 49·3 lbs., from the condensation of which 98·7 lbs. of water were collected. The comparison of heat expended and effect produced in this case is not satisfactory, owing, probably, to some error in measuring the condensed steam.

	Units.
98·7 lbs. of water, condensed from steam at 49 lbs. pressure, 992° latent heat, - - - -	97,910°
98·7 lbs. of water of condensation, cooled 6°, -	592°
Total, - - - -	98,502

The effect produced, making the proper calculations for loss by evaporation, as already described, was as follows:—

	Units.
592·4 lbs., heated from 70° to 210°, - - -	84,120
Heating tank, - - - - - - - -	21,608
Evaporating 10·15 lbs., at 212°; latent heat, 966°,	9,824
Total, - - - - -	115,562

Showing 17,060 units more heat used than there appears had been supplied, an error of at least 18 per cent., an amount so large, as compared to those on all the other experiments, that it has arisen evidently from a large error of observation in the quantity of water condensed. This part of the experiments was, indeed, the most difficult to carry out accurately, because there was no means of ascertaining when all the water had drained out of the steam space, especially when the boiling off experiments followed hard on those for heating, and it was desirable not to allow the water due to the steam contained in the steam space being added to the water condensed in course of the experiment. There can be no doubt that the observations on the *effects produced* were correct; it will be advisable, therefore, for the sake of the comparison, to be made presently, of all the experiments, to assume the heat units in the condensed steam to exceed those of the effects produced by about 4 per cent., and to take them, say, at 120,182. With this correction the number of heat units transferred to the water and the boiler per square foot, per difference of degree per hour, $\frac{120,182}{104' \times 156°} = 77.$

During the boiling-off experiment, which followed immediately, and which lasted one hour, 123·4 lbs. of water were evaporated, the mean steam pressure being 47·2 lbs., yielding 12·94 lbs. of water of condensation. The comparison here comes out quite satisfactorily.

135755A

	Units.
129·4 lbs. of condensed steam, 982° latent heat, =	127,070
123·4 lbs. of water boiled off, 966° latent heat, =	119,240

Showing a loss of 7·867 units, or a little over 6 per cent., and the number of heat units transferred per square foot per difference of degree per hour, $\frac{127,071}{104' \times 83} = 157·1$.

Circumstances prevented the author from reducing the two last experiments till nearly a month after they had been made; the unsatisfactory result in the trial of July the 12th, which then appeared, determined him to repeat the experiment, the boiler fortunately being still in his possession. It was set up accordingly in the same way as before, and the following trials made on the 17th and 18th of August:—

Third Experiment, on August 17th, 1869, on same Boiler.

Time	Temp. in Boiler	Temp. Condensed Water	Gallons Condensed Water	Pressure of Steam	Remarks
3·50	84°	210°	2·305	—	Depth of water 17·85″ in centre, 21·88″ from top of boiler.
				Lb.	
3·58	109	,,	2·561	32	
4·06	133	,,	2·561	31	
4·14	154	,,	1·911	31	Temperature of air throughout, 70°.
4·22	172	,,	1·970	30	
4·30	189·5	,,	1·959	30	
4·38	203·5	,,	1·411	30·5	
4·44½	212	,,	—	31	Depth of water, 18·15″ at centre, 21·50″ from top of boiler.
			14·633	30·8	Mean.
			·12		Amount drained out of steam space after experiment.
			14·753		

Fourth Experiment, on August 18th, 1869, with same Boiler.

Time	Temp. in Boiler	Temp. Condensed Water	Condensed Water	Pressure of Steam	Remarks
			Lbs. oz.	Lb.	
10·40	74°	210°	—	—	Depth of water in centre, 16·7 inches, and from top of boiler, 23·375″
10·48	96	„	21 7½	39	
10·56	124	„	31 13¾	40	
11· 4	146	„	20 7	40·5	
11·12	167	„	20 4½	40	Temperature of air, between 63° and 72°.
11·20	185·5	„	20 14	39·5	
11·28	204	„	20 3¼	39·5	
11·33	212	„	11 2	39·5	Surface of water 23″ from top.
			1 3½	—	Amount drained out of steam space after experiment.
			147 7½	39·7	Mean.

The experiment of the 17th August gave 882 lbs. of water heated from 84° to 212°, in 54 min. 20 seconds, by 147·53 lbs. of water condensed from 30·8 lbs. steam, and the comparison between the units of heat given out by the steam and absorbed by the water and boiler is as follows:—

	Units.
147·83 lbs. condensed steam, 986° latent heat, -	145,464
Effect produced:—	
882 lbs. of water heated from 84° to 212° = a rise of 128°, - - - - - - - - -	112,896
Heating boiler, - - - - - - -	18,114
15·4 lbs. water evaporated at 212°; latent heat, 966°, - - - - - - - - -	14,876
	145,886

Results agreeing very closely, too much so, in fact, to be quite accurate. The number of heat units transferred from the steam to the water, the latter being taken at a mean temp. of $\frac{84° + 212°}{2} = 148°$, and the former at 275°, giving a difference of 127°, was $\frac{145{,}464^{\text{units}} \times 60^{\text{min}}}{104' \times 54{\cdot}3 \times 127} = 127.$

The experiment of August the 18th gave 824 lbs. of water, heated from 74° to 212°, in 53 minutes, by 147·47 lbs. of steam at 39·7 mean pressure. The comparison of cause and effect is as under:—

	Units.
147·47 lbs. steam condensed from 39·7 lbs. pressure; latent heat, 989°, - - - -	145,847

Effect produced:—

	Units.
824 lbs. of water heated from 74° to 212° = 138°,	113,712
12·5 lbs. of water evaporated at 212°, - -	12,075
Heating boiler, - - - - - -	20,260
	146,047

Results also agreeing rather too closely, and with the error on the wrong side. It may be remarked here that there is great difficulty in measuring accurately the depth of water without some special arrangement of floats; its capillary attraction renders the simple foot rule used by the author a very unsatisfactory instrument.

The number of units of heat transferred per square foot per hour, for one degree of difference of temperature, was $\frac{145{,}848^{\text{units}} \times 60^{\text{min}}}{10'^{\text{sq}} \times 53 \times 143°} = 118.$

The results of all the experiments here recorded are collected in the accompanying table, to which also are added the results of other experiments to be hereafter alluded to:—

Summary of Experiments on Heating and Condensing through Metallic Surfaces.

Authority	Date	Units of heat transferred per sq. foot per degree per hour	
		Heating	Evaporating
W. Anderson, - -	July 6, -	63·0	
	,, 10, -	79·1	147·7
	,, 12, -	77·0	153·1
	Aug. 17, -	127·0	
	,, 18, -	118·0	
Easton Amos and Sons,	—	230·0	
		207·0	
		210·0	
Péclet, - - -	Prior to 1843,	335·0	
		315·0	974
			1020
"Hansa," - - -	—	152·0	
"Ripon," - - -	—	151·2	

With the exception of the first part of the experiment of July 12 there had been a very satisfactory agreement between the units of heat calculated to have resided in the steam and those absorbed by the boiler and the water it contained; it is fair, therefore, to conclude that the observations recorded were substantially accurate. How, then, are we to account for the great discrepancy in the results? Those obtained from the tubular heater being nearly 20 per cent. less than the average of the experiment of the 10th and 12th of July, with the double-bottomed boiler, while the latter were 36 per cent. below the mean of the results obtained from the very

same boiler, tested in the same way, a little more than a month later. Singular as these discrepancies are, however, the experiments may be said to be in perfect accord with each other, when compared with those recorded by Pêclet in his great work, *Traité de la Chaleur*. A double-bottomed boiler transferred 335 units in heating 1,980 lbs. of liquid from 35° to 212°. A worm or coil of steam pipe, immersed in water, gave 315 units in heating 880 lbs. of water from 46° to 212°, and 974 units in afterwards evaporating 550 lbs. of water in 11 minutes; a double coil immersed in water transferred 1,020 units in evaporating 132 lbs. of water in 5 minutes. In spite of the authority of Péclet, the author confesses to doubts as to the trustworthiness of the experiments. They were not made by the distinguished *savan* himself; no details are given by which the calculations can be checked; the materials of which the vessels were composed is not even mentioned. In one respect only do they agree with the experiments which form the subject of this paper, namely, that in boiling off very many more units of heat are transferred than in heating.

In Mr. Box's useful little work, a *Practical Treatise on Heat*, recently published, Péclet's experiments, above quoted, are given reduced to English units, and, further, some experiments made by Messrs. Easton Amos & Sons, on a vertical tube 1½ inches diameter, immersed 3′ 7″ in water, are recorded, which give a mean of 216 units per square foot of surface, for a difference of one degree of temperature, per hour, and in this case the condensed steam was collected, and the units of heat it had contained agreed very closely with the amount imparted to the water. The author, however, is in a position to know that the agitation kept up was very perfect. A board, nearly fitting the square wooden box which held the water, and having a hole in it, through which the pipe passed, was moved up and down regularly, at the rate of 60 strokes a

minute; this case, therefore, for reasons which will be alluded to hereafter, cannot enter into comparison with the experiments now being recorded.

A more satisfactory agreement, however, may be traced in examples of surface condensers. In the 1861 edition of Bourne will be found the leading dimensions of the engines of the "Hansa," by Caird & Co.

Two cylinders, 80″ diam., 3′ 6″ stroke, 25 lb. steam pressure surface condensers, with 3,584 brass tubes 1″ external diam., 7 feet long, the circulation kept up by two double-acting pumps, 21″ diam., 2 feet stroke. As usual in such descriptions some important fact is omitted; in this case the speed of the engines is not stated, but assuming the pistons to run 300 feet per minute, it would give 43 revolutions, a usual speed for large screw engines. Supposing the cylinders to be three-fourths filled with steam each stroke, 15,705 cubic feet of 25 lb. steam would be consumed per minute, equal to an evaporation of 1,464 cubic feet of water per hour in the boilers, yielding on condensation and cooling down to 120°, after allowing 5,624,953 units absorbed by the power given off, 90,717,585 units of heat. The condensing surface is 6,565 square feet, and the two double acting pumps, running 43 strokes, will deliver 49,536 cubic feet per hour, which, absorbing the heat of the steam condensed, will be raised 29°·4, or, say from 60° to 90°. The mean temperature, therefore, of the condensing water would be 75°, the mean temperature of the steam and water in the condenser will be about 166°; the mean difference in temperature between the two faces of the condenser will be 91°; and the number of units of heat transferred per square foot per hour, for a difference of 1°, will be 152.

Again, taking the Peninsular and Oriental Co.'s steamship "Ripon," with two cylinders 76″ diam., 7 feet stroke, having surface condensers, with 4,777 Muntz metal tubes 6′ 4″ long,

$\frac{3}{4}''$ outside diameter, and assuming 25 lbs. steam pressure and 300 feet of piston per minute, with a cut off at three-fourths of the stroke, it appears that 1320·7 cubic feet of water must be evaporated per hour, yielding on condensation and cooling to 120°, 81,836,025 units of heat to be taken up by condenser, after deducting 5,076,559 units of heat absorbed by work done. The quantity of water passed through is not known, but assuming it enter at 60° and leave at 90°, as in the previous case, the mean temperature would be 75°, the mean difference of temperature between the two sides of the condenser 91°, and the number of units of heat transferred per square foot per hour, for a difference of 1°, 151. These results accord much more closely with the experience of the author than with the experiments recorded by Péclet, or even by Mr. Box. Péclet enunciated the two laws, that substances of homogeneous nature with parallel faces, having constant temperature on each face, transmit heat in direct proportion to the differences of temperature, and in inverse proportion to the thickness of the substance. He made numerous experiments on discs $\frac{3}{8}''$ diam., and completely proved the correctness of the first law. The liquid heated was kept in motion by an agitator, but he found that to obtain comparable results it was necessary to work the agitator at a constant speed, for by varying its velocity the number of heat units transmitted varied also. This is the reason for the author's statement that Messrs. Easton Amos & Sons' experiment with a mechanical agitator should not be brought into comparison with cases where the particles of liquid are changed by natural circulation only, for it is evident that even the moderate current induced by the circulating pumps of a surface condenser considerably raise the number of heat units transferred. In trying to establish the second law Péclet was surprised to find that, although he varied the thickness of his plates twenty-fold, no difference in the heat transmitted could

be perceived. It occurred to him that probably his metallic surfaces were covered by an immovable or, at any rate, very sluggish layer of liquid, which, being a bad conductor, opposed so much resistance to the passage of heat that that of the plate became inappreciable by comparison. He accordingly constructed brushes which wiped the surfaces of the discs 1,600 times a minute, and under these conditions he found that the second law laid down held good also. It follows from the above that the duty of surface heaters or condensers will depend very much on the nature of the surfaces and the freedom with which the films of water in contact can be changed. As long as water is merely being heated the circulation is comparatively slow, but when it begins to boil it is more rapid, fresh particles are brought more often into contact with the heated plates, and hence the result obtained by the author, that more heat units are transmitted in boiling than in heating water. This view is further confirmed by comparing the velocity of current in the St. George's Hospital heater and the surface condenser of the "Hansa." In the former 323·4 cubic feet passed through an area of 4·1 square feet in 4¾ hours, at an average speed, therefore, of 0·28 feet per minute, and 63 units of heat were transferred per square foot per hour, for one degree of difference; in the latter case 49,386 cubic feet per hour flowed through 14·94 square feet, or at average speed of 55 feet per minute, and 152 units of heat were transferred. It would seem, therefore, that the rate of transfer of heat is a function not only of the difference of temperature, but of the velocity of the current; its nature, however, in the latter case cannot probably be determined without special experiments. Again, during the month which elapsed between the two sets of experiments on the double-bottomed boiler it is probable that the surfaces of the plates, which were unpainted, rusted; very likely the black oxide of the natural plate dropped off, and so presented

surfaces better suited to the transmission of heat, and hence the superior result obtained in the experiments of the 17th and 18th of August.

Péclet lays great stress upon the deleterious effects produced by air remaining mixed with the steam in the double bottoms or coils. He does not, however, give any evidence as to this, and, therefore, his statement should be received with caution, especially if we consider that the amount of air liberated with the steam from the water in the boiler must accumulate rapidly to a more considerable amount than that supposed to be partially displaced by the steam in the first instance, for while the steam is condensed the air is not, and can only escape in company with the condensed steam, or through taps provided for the purpose.

Although the experiments now laid before the Institution, and the investigations and comparisons entered into for the purposes of this paper have made the author feel much more confidence in dealing with surface heaters and condensers, there can be no doubt that our knowledge of the subject is still in an unsatisfactory state. It is, therefore, very desirable that members who may meet with opportunities of making experiments should take advantage of their position, remembering at the same time how important it is to observe every circumstance and condition, in order to obtain trustworthy results.

ADDRESS

BY

J. BALL GREENE, Esq., C.E.,

PRESIDENT OF THE INSTITUTION,

COMMISSIONER OF VALUATION IN IRELAND, ETC., ETC.

(Delivered on the Evening of February 9th, 1870.)

GENTLEMEN,

In attempting to review the present position and prospects of our Institution, I desire, in the first instance, to tender an apology for any short-comings observable in the course of my remarks, as from certain circumstances in connexion with a committee appointed during the last Session of Parliament, to which I need not further refer, my attendance at our meetings has been unavoidably less regular than I could have wished, and in consequence, it may not be in my power to discuss the papers communicated to us, in a manner suited to their importance; and I feel it the more necessary to premise this consideration, with a view of escaping too unfavourable contrast with my predecessors who have hitherto occupied this chair, for, as I have already expressed, in opening the session during which it has been my privilege to preside, so I beg to repeat the acknowledgment of the sense in which I hold the distinction you have conferred upon me.

In the few remarks I ventured to make upon assuming the office of your President, you may remember that I expressed some mistrust and diffidence relative to the efficiency of the subject of your choice during my tenure of so honourable a position; and I referred to deficiencies which I then foresaw as more than probable, owing to which I was led to

claim the exercise of your kind indulgence and co-operation, but the anticipation I then ventured to form relative to the continued interest in connexion with our proceedings, has not resulted in any disappointment as regards the character which our Institution has hitherto attained, and I think I may congratulate our members on this fact; taking into consideration the stagnation which, I regret to say, still exists in regard to the execution of engineering projects, by which the scope of professional practice is more circumscribed than at many former periods.

I am happy to find, however, that our financial condition has not declined in this, the thirty-fourth year of our existence, as appears from the audited account in the last Report of Council, by which we learn that a balance of upwards of £65 remains in favour of the Institution, while a sum of £214 in the new 3 per cents. represents our funded property.

Death has deprived us of one Member, Mr. Talbot of Bray, but, on the other hand, we have gained three new Members and two Associates. Inclusive, therefore, of our two distinguished Honorary Members, our numbers at present are increased to seventy, with fourteen Associates.

An average number of Papers (say sixteen) have been contributed since the month of January, 1868, while the Donations presented to the Institution have not diminished in number or value, so that, under the present circumstances, our general relationships with cognate public bodies continue undisturbed; and we have to record an improvement which, however slight, affords subject of congratulation, as well as encouraging prospects for the future.

I may mention, that owing to the death of Mr. Radcliffe, a change of Trustees has become necessary; Sir Richard Griffith and our Vice-President, Dr. Downing, have, however, kindly undertaken the trust.

The papers read before us represent the range of subjects

with which, as a Profession, we are conversant, and if they are not of as pretentious character as various communications which appear in our Transactions, their obvious utility will render them well worthy of attention.

In adverting to the valuable communication of Dr. Kidd, I may embrace the opportunity of expressing the gratification I feel at what may be termed the introduction of the lay element amongst us, as it not only tends to relieve our profession of any charge of exclusiveness, as regards the sources of information we employ, but conduces towards securing breadth to our contributions, as well as variety and vitality to our proceedings, and, I believe, I only reflect the general opinion in assuring Dr. Kidd that, so far from considering an apology necessary, we welcome him with pleasure as affording "new blood," and thank him for his communication.

The subject he treats of is of no secondary importance, as, in consequence of the high pressure water-supply recently introduced into the City of Dublin, it was only to be expected that certain provisions would from time to time become necessary to obviate accidents, which, it was probable, might arise in practice, and it is one of such casualties that the present mechanical contrivance is designed to prevent.

His attention was called to the necessity of a remedy, by the flooding of the upper part of his own house, in the winter of the year 1866-67, owing to the bursting of a pipe from frost, as also to the total cessation of water-supply for a considerable period, from the presence of frost in the rising main.

He refers, also, to the circumstance of the necessity found in the City of Glasgow, for cutting off the water-supply of no less than 280 houses in one night, from the bursting of pipes, during the season before-mentioned; and he further states that, in the same period, the estimated loss in London, from a similar cause, amounted to fully half a million sterling.

To meet the exigency arising from either of the two causes, *frost* or *immoderate pressure*, the idea was conceived of relieving the pipes themselves, both principal and tributary, when not actually in use, as no increased strength of pipe* (the only alternative) could resist the extra expansion of water by frost. The two established methods of domestic water-supply, namely, by pipe or cistern, are shown to involve, virtually, only one principle, resulting in the constant occupation of the pipes, by water in the most effectual condition to create damage.

Our present design hardly admits a detailed review of the description given, as reference can be made to the paper itself, so I pass to the principle of the method before us, which consists of the employment of a small regulating tank, (say 22″ × 8″ × 14″) in the basement story, supplied with a float ball that exercises a double action on the rising main.

By this action a house cistern on the upper story is supplied, at the same time that the supply and secondary pipes are emptied by the discharge of the cistern surplus, through an overflow pipe in connexion with the basement tank, and this in turn being filled floats the ball, and closing the supply cock, empties the pipes by opening another.

The whole process of supplying the house, and relieving the pipes, is so simple, that Dr. Kidd applies the term "self-

* Since reading the above I have received Professor Christison's address, delivered before the Royal Society of Edinburgh, December 7th, 1868, in which, at page 407, he refers to a paper of Major Williams, R.A., who, in the year 1786, made experiments in Canada with a view of ascertaining "the force exerted by water in freezing," from which it appears that an iron bolt or plug, weighing 2½ lbs., driven with force into a 13″ shell filled with water, was, at the moment of freezing, propelled with such violence as to drive it distances varying from 325 to 415 feet, a column of ice at the same time exuding through the fuse hole from 4 to 8½ inches; the effect of securing the plug being further to split the shell itself, plates of ice protruding through the fissures in the metal, originally of a thickness from 1½ to 2¼ inches.

acting," inasmuch as the tank being necessarily in frequent use, the purposes required are as easily effected as turning gas on or off.

An ingenious provision is also made for an increased basement supply (should the tank water occasionally prove insufficient), by means of a two-way action in the exhausting cock, which is furnished with a second aperture; or, in case of dispensing with this provision, a second cistern of larger dimensions, with ball cock attached to the rising main, may be resorted to.

I cannot, however, omit to say, that the intermediate room cisterns, with float balls, which are proposed to clear the distribution pipes, appear to depart a little from the simplicity of the scheme, while the alternative suggested for dispensing with the floats seems scarcely less complex; but as the invention has already been practically established, improvements are to be expected, on occasions arising for the introduction of new, or the replacement of old work.

Mr. Geoghegan (one of our Associates) occupies ground nearly similar to that just mentioned, and his claim to preference would seem to rest on the invention of *self-acting* apparatus; but that term in effect equally applies to Dr. Kidd's contrivance, and, as *already in practice*, it has so far the advantage of Mr. Geoghegan's invention which, if I understand rightly, has not as yet been generally adopted.

In opening his communication, Mr. Geoghegan refers to certain cases of the failure of pipes, cocks, and taps, and he ascribes the greatest source of anxiety, encountered by the Hydraulic Engineer, to the expansion of confined air in the pipes, which, he considers, have yet to be provided with "a perfectly reliable self-acting valve" to admit the escape of air without loss of water.

He is further of opinion, that the dangers referred to are increased at night, owing to the cessation of supply service,

the accidents, however, being chiefly limited to street mains, but the difficulties have hitherto proved so numerous that all remedial measures have proved only partially successful.

Under such circumstances Mr. Geoghegan produces his contrivance, differing from that of Dr. Kidd by the introduction of an air principle, which, confined in an inverted receiver, becomes condensed, as the cistern fills, and presses sufficient water into a second vessel to float a ball furnished with a counterpoise, both of which act alternately in opening and closing the inlet cock, and, as every service only affects the main head of water, one action is relied on to supply or discharge water, an additional full turn of plug being effected by a three-way motion.

While by no means undervaluing this invention, I may be permitted to say, that, as the action of the contrivance depends on a decrease of head water in the main cistern, its *principle* will merge in that of Dr. Kidd, from the fact that in both cases, *withdrawal* of water, differing only in method or source, is dependent on unavoidable or involuntary personal action; and, it may also not be out of place to consider, how far the expedient adopted for arresting evaporation, by sperm oil on the surface of the water, has been sufficiently tested, as any failure, in securing sufficient pressure to float the ball contrivance, would be fatal to the scheme, however infrequently occurring; but, I merely suggest such considerations for the sake of caution, having to hail with satisfaction the social benefits such inventions as those of Dr. Kidd and Mr. Geoghegan are calculated to confer.

I think the paper of Mr. Anderson, our Ex-President, will, with propriety, follow here for consideration, as an allied attempt in the same direction, its subject being of equal, if not greater importance, from the fact that he would not only utilize a minimum of motive power by suitable hydraulic machinery, but confer the advantages of water supply, from

the most insignificant and otherwise unavailable sources, over extended areas, by means of his comparatively cheap and simple "domestic water works."

It is only a few years ago that his attention was directed to this object, owing to a want expressed by a gentleman in Dorsetshire, who required a water supply for his garden, the source of such supply being, however, limited to the River Stour flowing several feet beneath, having an available fall of only 3 inches, which represented not more than 0·04 horse-power.

The quantity of water required to be raised, 26 feet per minute, amounted to 5 gallons, and Mr. Anderson immediately recognized the application of a Poncelet, or undershot stream wheel for that purpose, which, furnished with curved buckets, and fixed in a cast-iron case, would work a pair of connected pumps, by means of an attached crank-plate with holes to receive a crank-pin turning in a cast-iron block.

I cannot, of course, here refer to the minute particulars of this interesting contribution, but I may express a hope, that, when appearing in full in our Proceedings, it will be so effectively illustrated, as to afford exact information respecting the machinery, which has already been found so successful.

The success of the Poncelet wheel led to the construction of many others, of various dimensions, on the same principle, and for varying falls, and lengths of rising pipe.

In the case of higher falls (say 2 feet), the speed of the wheel was regulated by the employment of a sliding plate introduced between the head-race and wheel; and this last is set in motion or stopped by a common wooden sluice working in a cast-iron frame by means of a gun-metal screw and nut.

One of the wheels in use, 3 feet in diameter, and supplying $\frac{3}{4}$ of a gallon of water, 8 feet high per minute (constructed for a Mr. Jackson, near London), is described as representing horse-power only to the amount of 0·018, being but $8\frac{1}{2}$ inches

wide, while one for Lord Manvers is 5 feet in diameter, and 2′ 6″ wide, the pumps in both cases being made to correspond proportionally.

As the falls increase, we learn that the comparatively rapid Poncelet wheels become inapplicable, and a fall at the height of 6 feet will require the employment of turbines to work the pumps; while, again, these turbines at, say, a fall of 20 feet, owing to their insufficient size and excessive velocity, become displaced for the admission of simple hydraulic engines, or horizontal cylinders with slide valves, furnished with piston-rod, crank, fly-wheel, and crank-plate to work pumps, whose power, like that of the wheels before-mentioned, may be varied by shifting crank-pins.

One of these engines (6″ in diameter, for a fall of 19′ 6″), has recently been constructed for the Duke of Buckingham to raise 5 gallons of water per minute to a height of 150 feet, by pumps similar to those abovementioned.

The accumulation of leaves and weeds has, however, been found an inconvenience in the use of these hydraulic engines, but this impediment is overcome by the use of proper gratings, which, in low falls, should be so large and inclined as to be easily cleared by raking.

In this condensed review, I must unwillingly omit allusion to many points of interest contained in Mr. Anderson's paper, but I should not close my remarks without observing, that, when the fall exceeds 3 feet, he has ventured, successfully, to alter the ordinary ratio subsisting between the diameter of Poncelet's wheel and the fall.

To exemplify this experiment he refers to the case of a wheel erected, to work $4\frac{1}{2}''$ horizontal pumps, in a village in Essex, the diameter being 7′ and the fall 5′ 9.″

We cannot, I think, overestimate the invention of our Ex-President, as an extended supply of soft water, from sources hitherto unavailable, by easily obtained agency, must conduce

to domestic convenience, as well as be productive of ulterior results in agricultural or manufacturing industry.

Hydraulic projects, also, in becoming objects of increased solicitude, are not only certain to enlarge the field of our professional practice, but must result in the simplification and improvement of the machinery required by the Hydraulic Engineer; and his attention, I may also suggest, will always be well directed to the *sufficiency*, at *all* seasons, as well as to the *quality* of his water supply, for, the geological influence of its passage, or source, in varying mineral or organic conditions, must always form a considerable element in the economic results to be expected.

Though our attention has hitherto been directed to questions of original invention, or adaptation of principles already known, Mr. John Smyth's paper on the repair of the leak in the main embankment, and construction of the Bann Reservoir, situate at the base of the Mourne Mountains, appropriately follows, as sustaining the rather hydraulic character of the last session.

Mr. Smyth, being not only Engineer to the Bann Reservoir Company, but, himself, a share and fall-holder, must be regarded as specially qualified to treat of the subject, but time forbids more than a rapid sketch of the principal features of his description.

The necessity, in the first instance, for the construction of the Bann Reservoir arose from the repeated deficiency of water felt by the mill-owners* at uncertain periods,

* I have just seen a striking, and, perhaps, peculiar remark, respecting the influence exercised by the interests of mill-owners, which it may not be out of place to quote.

At page 11 of his Presidential Address, read last January in London, before the Institution of Engineers, Mr. Vignoles says, relative to grants of concessions made by the French Government for inland river communication:—"Most of these were rendered abortive, and abandoned, from uncertainty in the supplies of water, on account of irregular rain-fall, and from the pre-existing monopolies

especially in the summer season, and, as a remedy for this inconvenience, the principal fall-holders on the River Bann formed a company in the year 1835, and Mr. Bateman, having ascertained the capacity of the several catchment basins of the district, recommended the erection of embankments to impound an excess of 35 feet of water, over that contained in the original area of Lough Island Reavy.

The principal reservoir (situate 440 feet above the level of the sea), consisted of 253 acres, and, with Lough Corbet as an auxiliary, it was completed about four years subsequent to its commencement.

The extent of Lough Island Reavy itself being only 93 acres, the excess calculated to supply the mills amounted to 38′ 6″ of the entire depth of the impounding reservoir.

From his own calculation, Mr. Smyth estimates that, as the rain-fall at the Lough Island Reavy Reservoir exceeds the average (36″) of Ireland generally, by 12 inches, it would fill the reservoir basin (with a capacity of 280,000,000 cubic feet), twice a year, due allowance being made for evaporation and absorption.

He also mentions, that, though the reservoir is seldom empty, the dividend payable to the Company (only, say, 3 per cent.), is rather of a discouraging character, but, as he attributes the deficiency, in some measure, to certain expenses and damages for which the company were made liable, in connexion with the flooding and scouring of the River Muddock, as well as to the repair of the leak, in the main embankment, now in question, he indulges the expectation of an improvement in this respect, from the increased occupation of the falls on the River Bann, likely to follow the completion of the Banbridge Extension Railway.

of the millers, who appear, at all times and places, to have been, as they still are, the natural enemies and thorns in the sides of the hydraulic engineer."

I think, however, the gradual introduction of steam motive power will set matters right between the engineers and the millers.

The embankment in which the leak occurred is the principal of the four required to impound the water in the reservoir, and being 700 yards in length with a maximum depth of 40 feet, it rises 5 feet above the level of the water, to the top, at which it is 12 feet wide.

A suitable dry foundation having been selected, the puddle trench was cut to a thickness of 12 feet at a depth of 40 feet *beneath*, and 8 feet *at* the surface.

Mr. Bateman further introduced a novel expedient to protect the inner sides of the puddle and slope of the embankment, consisting of compressed, and almost dry peat, to form casings 3 feet in thickness, and one of these would be surmounted with 18 inch gravel, and 2 feet stone-pitching courses, as usually overlaid the inclined inner surfaces of reservoirs.

The embankment thus became all that could be wished, and its failure is attributable to defects in the construction of the discharge culvert beneath, the percolation of water being chiefly due to rough backings of rubble erected behind its side walls contrary to Mr. Bateman's advice, which cutting through the puddle barrier, as well as the embankment itself, formed, in fact, a filter, as if leakage had been the object in view.

Not that, I would say, such a rubble support, or, as it were, spandrel wall, if *properly constructed and puddled*, would have been a violation of correct principle, but, many of the joints of the culvert itself, from the pressure, served as so many fissures or inlets for water, by the removal of the mortar, while the moist foundation beneath the disintegrated concrete in which the invert was set (with even a space intervening between these latter), in addition to the exterior roughness of the arch masonry (undressed to the circle), and the partial subsidence of the stone pitching, afforded increased evidence of the disaster.

Under these cirumstances, many temporary expedients were adopted, with varying success, such as oakum caulking and Roman cement, when with a view to lasting effects it became

necessary to consult Mr. Bateman, and he advised that, the embankment being laid bare to the culvert, encasing walls of solid masonry* should be erected on either side of the central puddling, in the manner of a coffer-dam; but as this would have been an expensive proceeding, it was considered desirable, with a view to retaining the present use of the water in the reservoir, to persevere in applying a temporary remedy.

Owing to the interest I feel in hydraulic projects, I may be permitted to digress for a moment in adverting to the benefits derived by my fellow-citizens, from the completion of the water-works of our city, as they advanced to their termination, almost uninterruptedly.

Some delay arose from a leak in the puddle wall of the main embankment of the Roundwood reservoir, which, from its position near the culvert, would seem to have been not very dissimilar from that under consideration, though contrasting much in the completeness of its repair, and this may be ascribed to the prompt action taken by Mr. Neville and Sir John Gray; the latter of whom must be regarded as the most active promoter of the undertaking from the commencement,† and, indeed, the expression of our thanks is only a just tribute to Sir John Gray for his perseverance against all opposition, to which we are mainly indebted for the benefits at present enjoyed from the completion of the works, projected, in the first instance, by Mr. Hassard, one of the members of this Institution.

Indeed, in this connexion, it may not be irrelevant also to refer to the part taken in carrying out these works by my lamented relative, the late Henry Greene, whose sad fate you are all aware of, and I embrace the present opportunity of expressing my own personal acknowledgements to the members

* In discussing Mr. Smyth's paper, it was well observed by Mr. Stoney that no method of securing the embankments of reservoirs could effectively supersede that of masonry with offsets, as shown by instances in Spain, which, after a lapse of centuries, have proved as effective as when first constructed.

† *Report of City Engineer*, p. 72.

of the profession, to which he (in common with ourselves) had the honour to belong, not only here, but in England, who, in conjunction with other sympathizing friends, so promptly displayed their appreciation of his private character and public services, by the generous rescue of his bereaved survivors from the calamitous effects of a misfortune, incurred for the public benefit, by which he was deprived of a considerable private fortune; while such an instance as this may also be practically advantageous, in the warning it affords to contractors of the danger of insufficient estimates arising from unexpected impediments.

The rival estimates, at the commencement of the works, were so numerous, that, when the execution of a tunnel from the principal reservoir at Roundwood (through the strike of above two miles of rock) unfortunately devolved on Mr. Greene, he was obliged himself to bear the expense of an undertaking which the citizens now enjoy; but perhaps no adequate estimate could have successfully competed, had the unusual quantity of underground water been foreseen, or had due provision been made for the obdurate character of the interstratified quartzite to be excavated, which, in this schistose district, dips at high inclinations; and (as I had an opportunity of observing with Sir Richard Griffith) it sometimes assumes the character of solid or amorphous quartz-rock, similar to that of Bray-head.

Little remains to be said in resuming the subject of the Bann reservoir embankment, beyond a rapid reference to the temporary repair I have already mentioned, which, in the year 1867, was entrusted to Mr. Smyth, who found it necessary to lay bare and examine the defective joints in the masonry of the culvert for some distance, which he filled with a grout, composed of a paste of Portland cement containing a bond of comminuted cinders, in preference to sand, which latter has a tendency to subside rather too quickly.

Having next applied the requisite puddling, he repaired the foundation with Coal Island fire-brick, as also the invert, and any settling observable, such as the slope pitching of the bank, which was raised, and stepped to prevent further subsidence; so that by this means, the leak, though still slight, was reduced to a minimum, and considered by the directors of the Bann Reservoir Company, as practically inappreciable in reducing the water-supply required for the season.

The adaptation of the peat principle forms the speciality of Mr. Smyth's paper—this element having been introduced with a view to protect the puddle from the settlements and cracks arising from contraction, to which the former, by its elasticity, would accommodate itself like a cushion or sponge, and I think we cannot too much encourage such experiments, for, though the expedient before us will not bear comparison in regard to durability, with the design of Mr. Bateman, its obvious utility, or in certain cases, necessity, will commend a record of it as worthy of a place in our Proceedings.

I have rather adopted a sort of rough classification of subjects in the consideration of our communications, than their precedence in the order of date; and, in consequence, I propose to make only a short allusion to a mechanical paper by our Ex-President, for the experiments which form its subject are hardly in a sufficiently advanced state for lengthened consideration.

Mr. Anderson states that the subject of "heating water and condensing steam by tubular and double cased vessels," is one about which very little accurate information exists, and hence the experiments he records.

In addition to the absence of any definite goal in view in the present state of this inquiry, the tabular results necessarily assume so complex a form, as to preclude any attempt, on my part, to arrive at a sufficiently definite conclusion to form a clear idea of their relative value; but the present

stationary position of the inquiry will rather stimulate further endeavours, than offer any discouragement in the prosecution of investigations, the importance of which are obvious.

The means available for the purpose of determining the respective disposal of the several units of heat, may on a future occasion, prove more suitable for the purpose, as Mr. Anderson refers to certain deficiencies with respect to the capacity of the boiler, as well as of the inlet and outlet pipes of the apparatus employed; but desiring him the fullest measure of future success, to whatever conclusion it may lead, I think we had better refrain at present from premature observations, which might be rendered utterly worthless hereafter, in the presence of results as yet undetermined.

Colonel Meadows Taylor (one of the Members of our Council), contributes a communication on "A Practical Improvement in the Use of the Plane-table," the effective application of which, I would say, comes out to view in the conclusion of his paper, in the reference made to its value in the hands of native Indian surveyors, instructed in its use by himself.

We are all aware of the displacement of this and other primitive methods of surveying by the introduction of modern improvements; but in the absence of better instruments, and in backward or remote localities, especially in such a country as India, there is no saying how far this design may not provide a substitute, perhaps, more suited to the capacity of a simple population in effecting a survey of their native village lands; the original plotting of which can be easily transferred to the fair plan, without the intervention or trouble of any field book.

The improvement before us consists in the application of the principle of the Theodolite to the Plane table, by means of finely perforated rising ruler sights, and a perpendicular hair,

at either end of a scale intervening in a straight line between them, by which back, as well as foresights, may be taken.

The table is likewise supplied with a plummet adjusted in the centre underneath the revolving pivot, for the purpose of being placed in a precise position over the several bench marks at every new station.

We need little description in regard to the manner of conducting a survey with this instrument, it being sufficient to explain its principle, which consists of proceeding by means of successive, back, front, and intermediate check sights (from and to the original and advancing bench marks, or other points in the sides of triangles ascertained by measurement), which, on clamping the table, will, if the work be correct, exactly command the points already observed at the several flag-staff stations; side offsets (or those to irregular boundaries), being measured from the bases or perpendiculars already determined to check or prove the triangles completed, and plotted on the paper in the progress of the work.

Colonel Meadows Taylor states, that, in some intricate surveys made on the foregoing principle, no perceptible error was discovered on testing the work by the Theodolite; but as such a survey is wholly dependent on the surveyor's eyesight, in correctly observing the several flag-staff stations, or bench-marks, he recommends that they shall be in closer proximity than would be found necessary in the ordinary practice.

One of our promising Associate members, Mr. William G. Strype, contributes "A Description of the Iron Lattice-girder-road Bridge, recently erected over the Boyne."

I may mention that Mr. Strype is the son of our late Member, Mr. George H. Strype, whom he has succeeeded as manager of the iron-works carried on by the firm of Grendon and Co., Drogheda; so that his position invests the details of his account of this bridge with an authenticity to be relied on,

rendering it, in fact, a *working* paper, which assumes so much the character of a *specification*, as to supply the information required for the construction of a similar design elsewhere.

Considering the time at our disposal, and apologizing for the weariness I may perhaps have already inflicted, I cannot at this late hour propose to consider this communication as its merits would probably demand, so I shall limit myself to a few general observations.

There cannot be a second opinion as to the advantages, in some respects, to be derived from the substitution of the Railway system of Bridges for that hitherto in use for the conduct of ordinary road traffic; and in the instance before us, a partially decayed wooden structure, which was destroyed in consequence of a flood early in the year 1867, has been replaced by a durable and elegant iron lattice-girder bridge of 120 feet span (120 tons in weight), the component parts of which have been manufactured at the works of the Messrs. Grendon, and adjusted in their respective positions under the superintendence of Mr. Strype.

Owing to the contrast which exists between the application of the same description of bridge to different purposes, such as to railways on the one hand and public roads on the other, whereby, in each case, strains can, or cannot be modified, according to the certainty or variability in the weight and direction of passing loads, great care has been taken to secure the present structure from future disaster, by applying a sufficient test, which the specification stipulated should amount to a distributed load of 350 tons; and although it was subsequently found impracticable to adhere literally to this provision, Mr. Strype is of opinion that the test actually applied, amounting to about one-half that specified, or (including the weight of the bridge itself) 180 tons, was amply sufficient, as it was not probable that the bridge would be required to sustain a greater weight.

The greatest economy was exercised by the County Surveyors interested in the erection of this bridge, and the original abutments, as far as possible, were used for the new structure, by strengthening and extending the foundations, and raising ashlar masonry as far up as the corbel courses, and thence to the top, cut-stone.

The roadway of the bridge is 16′ 8″ wide, and it is overlaid by successive layers of covering, composed respectively of chipped wood, sand, shingling, and asphalt.

When this paper appears in our Proceedings, the illustrations will no doubt add much to its perspicuity; meantime I may observe, that it strikingly exhibits the union of the two great sections of which our profession is composed; for the construction of bridges is no less the speciality of the general than of the mechanical engineer, being manufactured work, equivalent to machinery; and I can only express a hope that this union will, so far from being impaired, continue to become, in future, even closer than before.

By the gradation I have mentioned, we pass to the "description" given by Mr. John T. Crosthwait, of the St. John's Wood Underground Railway, which is of a very detailed character, and, in fact, rivals the previous communication, as also possessing rather the character of a *specification.*

We are aware, from the position occupied by Mr. Crosthwait—namely, that of resident engineer—that no one is more competent to call our attention to a subject with which he is officially conversant; and as it is one connected with general engineering, I feel the more tempted to refer to, at least, a few of the leading features of his paper.

It is but a few years since the construction of tunnels and underground railways appeared to be almost chimerical, though, at the present time, from habit, we no longer remember them, as having been chief amongst the triumphs accomplished by the engineer.

In carrying out the work of excavation, in the instance before us, the necessary maintenance of the street sewers, mains, drainages, and public traffic is described as offering impediments which it was necessary to encounter, except at one point where the Company were empowered to suspend the traffic for about three months; but the underground railway passage of a heavily-laden train, each way, every four minutes, counterbalanced this privilege, as the combined vibration above and below rendered the timbering and new work a continual source of anxiety.

The comprehensive character of this paper, and the difficulty of extracting suitable selections, will appear more fully, if we consider that it embraces a detail of the several gradients (very irregular, from conformity to the superficial profile), the varieties of roofing, retaining walls and counterforts, junctions, stations, covered ways, gas and water supplies, signals, telegraphic communications, permanent way, road bridges, drainage, &c., &c.

Having myself had some experience in the construction of railways with Mr. Brunel, I think I am in a position to acknowledge the value of the details supplied by Mr. Crosthwait, and I am inclined to think that such *working* papers as his will frequently attract students in engineering to a perusal of our "Proceedings;" especially, I would think, those under the guidance of my friend Dr. Downing, who so ably fills the Chair of Engineering in this great University, whose hospitality we have so long enjoyed.

Amongst the numerous changes in the gradients throughout the whole line (which, almost the entire way, is up a heavy incline, having an average rise of 50 feet per mile for about two miles from the junction, with an average gradient of $\frac{1}{66}$ for the heaviest portion of the line), it is mentioned that the gradient most severely felt is that of $\frac{1}{60}$ for a distance of 720 yards, commencing at the junction,

as the train, on leaving, instantly ascends it, while returning, it becomes necessary to put on the break half way down, in order to come to a stand at the station below.

It also became necessary, for the most part, to construct the Baker-street junction with the main, or metropolitan line, and the several covered ways consisting of five different classes, independent of each other; as, in some instances, no more space remained for construction than about 12 inches, the exceptions being of the kind termed the "ordinary 25 feet covered way," from the absence of speciality; and arches springing from transverse girders, with concrete backings to strengthen the haunches, were required in other cases, with further varieties which I must forbear mentioning; but besides the opens, the road pitching was at times removed and restored, layers of asphalt and concrete having been introduced.

Before passing to the next paper I may refer to the laying out of the centre line, which is described as beset with numerous obstructions, arising from public traffic, intercepting buildings, &c.; but I might suggest that many difficulties in practice will often be obviated by not adhering too rigidly to routine practice, or mere theoretical precedent.

With every desire for Mr. Crosthwait's professional advancement, I may call special attention to his elaborate description of the Regent's Canal wrought-iron Bridge, constructed for the use of the St. John's Wood Underground Railway; and I would express regret, that the proposal for a central terminus* in our own city should, by falling to the ground, have rendered Dublin enterprise a striking contrast to that of London and other cities.

I proceed to the contribution of our Treasurer and fellow-Member, Mr. Charles P. Cotton, the title of which excited

* This project, and the introduction of street tramways for horse or locomotive draught, are again spoken of, we may hope, at last, seriously.

some curiosity, being "Some Remarks on a Novel Means of Transit for Minerals in the County of Sligo," and though the precise locality is not specified, I take it to be "Glencarbury," a portion of the estate of the late Erasmus Smith, situate on the King's Mountain, in the county of Sligo, where sulphate of barytes has been discovered in considerable quantities.

This means of transit, though acting by weight, without intervening supports, in a sloping direction, instead of by steam motive power, may probably be considered analogous* to the system of the "wire-tramway," invented by Mr. Hodgson, who suggested it to Mr. Ffolliott Barton, the proprietor of the mine; and the well-known principle of the self-descending and returning trucks on the steep double lines of tramway leading from certain quarries or collieries is similarly suggestive, as—say, in the case of the Austrian Lignite Mines in Bohemia, where the means just mentioned is in operation for various, and, often, considerable distances, on highly inclined tramways, but still I concur with Mr. Cotton relative to the importance of recording the present instance.

Assuming "Glencarbury," as marked on Sir Richard Griffith's Geological Map of Ireland, to be the exact locality in which the mine is situate, I may observe, that a lode, or deposit, in veins or pockets, yielding almost unmixed sulphate of barytes, is a rare circumstance, as it usually forms only a portion of the "gangue," or assemblage of minerals and "gossans" which accompanies the ore of metallic lodes, as in those, for instance, of the West Carberry or Bantry mineral district of the county of Cork, where barytes is also raised for export.

* But only analogous, as I have been subsequently informed by our Secretary (Mr. Stoney), that the author does not regard the principle of the above invention as identical with that of the wire-tramway.

I regret having unavoidably lost the opportunity of hearing Dr. Downing's late paper, containing an account of the combined use of the wire cable and hempen rope for a purpose similar to that described in Mr. Cotton's paper.

The mineral occurs in the upper carboniferous limestone, a formation presenting, for the most part, the horizontal stratification and precipitous escarpments mentioned by the author, and, as it is the predominant mineral for which the veins or lode is worked, an analogy is suggested (both as to the unusual mode of occurrence and quantity supplied), with the remarkable deposit of schistose steatite interstratified with the primary quartzites and schists which occur on the western shore of the county of Donegal, at Maghery, near the village of Dunglow.

"The means of transit" of the barytes from a height of at least 1,000 feet, consists of a half-inch endless wire cable, 4,760 feet long, and 23 hundred weight, revolving, uninterruptedly, round an inclined upper and lower horizontal pulley, by the action of 10 attached loaded skips or boxes, which, descending successively, deliver mineral through an aperture in a receiving platform, at the rate of half a hundred weight per minute, 10 empty boxes being at the same time carried up the ascending side of the rope to be replenished with mineral.

The upper pulley, furnished with a break, is 6 feet in diameter, and 6 hundred weight, and it is situated close to the principal pocket or deposit of barytes, at a distance, horizontally, of 2,200, and vertically, of 1,050 feet from the lower, which may be adjusted to provide for any stretch of cable, by means of connexion with a balancing water box or vessel filled to obtain the amount of pressure required to counteract the effects of slackening, and in proportion to the strains on the bearings of the pulleys.

Mr. Cotton alludes to the difficulty of investigating strains in connexion with such catenaries as those under consideration, and, assuming certain data, he estimates the approximate strain as exceeding the maximum of 21 hundred weight, allowed in Newall's tables as the working load for such a rope as this; but, notwithstanding, these strains (according to

Mr. Stoney's remark) seem to be, theoretically, reducible to those of half a suspension bridge, and they can be ascertained in the same manner.

It is a remarkable circumstance, in connexion with a cable of such an enormous curve or span, that the attached boxes or skips, though uncovered, should not be affected to any serious extent by the vibratory motion arising from the action of high winds; but, I would suppose, that in addition, perhaps, to the advantage of a comparatively sheltered situation, further protection is afforded from their influence by the speedy removal of the descending mineral to lower, and, in consequence, calmer levels.

The experiments having hitherto proved so successful, I would express a hope that Mr. Barton may be able to devise any further practical improvements found desirable, such as a means of obviating the inconvenience arising from the frequent renewal of the stationary wire hooks, which might, perhaps, be effectively transferred to the suspensory gear of the skips, provision for their reception being made on the cable; and any means of increasing the durability of the latter, by securing it, as far as possible, from the inequalities of wear, due to friction or attenuation, will add much to the value of the original design.

I should have wished, if possible, to close my hasty reviews of the several papers of the session by referring to the communication of Mr. Alexander M'Donnell (one of our Vice-Presidents), relative to the sliding crane used for the removal of machinery in the Inchicore workshops, but, as it has not yet been embodied in writing, I can only hope he will prepare it for publication, with a view to the preservation of the interesting details we have heard.

The course I have hitherto been led to adopt in addressing you has been the result of an opinion, to the effect, that (at least occasionally), the paramount duty inherent in the Presi-

dent of your Institution, acting, under your kind auspices, in a representative character, is that of appreciating and exhibiting the value attached to the voluntary performances of our fellow members, as we could expect nothing from deficiency of interest in our own Proceedings, but, that it should be, proportionately reflected by others, whose esteem it is desirable to secure, and, in consequence, I have endeavoured to study the communications that we have been favoured with during the session, with the amount of respectful attention to which the labours of their contributors entitled them.

However I may have discharged these official obligations, the aim of my efforts, at least, will, I trust, be in some measure secured, notwithstanding the limited opportunities left me for more suitable preparation, in consequence of difficulties of an unusual character which have for some time unexpectedly attended my public position as Commissioner of Valuation, owing to which I had almost inclined to rest satisfied with the observations it has been my privilege to submit; but, gentlemen, however precluded from entering upon the details of a more enlarged design, as originally intended, I should hardly pass over in silence some reference to the general state of engineering at present, as well as to a few of the more extensive works which have lately been completed.

As already mentioned, engineering projects continue in a more languishing condition than we could desire, and even the signs of a more promising future do not yet afford sufficiently sanguine anticipations for immediate encouragement; but as the present state of public depression passes away we may hope for more cheering prospects.

I trust, however, that the prosperity of our University School may continue as heretofore, for, in stating the foregoing views it has not been with any intention of inspiring feelings of dejection, as, in my opinion, an early professional education will, at all times, be almost a requisite for many

besides engineers engaged in extensive undertakings (which, after all, is the lot of comparatively few), and I would also think that agents of estates, and others interested in the improvement or disposal of property, as well as building-surveyors, agriculturists, valuers, &c., will all be in a better position to pursue their respective objects by possessing the superior qualifications and stamp a University course of instruction is calculated to confer, than if devoid of such systematic and special cultivation.

Should the legislative expedients now in contemplation hasten the advent of a more prosperous period, the unhappy circumstances hitherto surrounding our unfortunate country may be dispelled, and replaced by a corresponding increase of the improvements and projects in which we have, in comparison to other countries, been so long deficient; and should Government be successful in effecting a satisfactory arrangement in connexion with the occupation of land in Ireland, we may reasonably hope to participate in the benefits arising from the restoration of public confidence and enterprise likely to ensue.

Though disinclined to draw comparisons with the improvements and works of other countries, too unfavourable to those of our own, I fear, that, in numerous particulars, we shall still be obliged to acknowledge a contrast, for which it is difficult to assign an adequate cause, if (though, perhaps properly, pleading the adverse pressure of factitious circumstances) we altogether refuse to admit some degree at least of public apathy and indifference.

Possessed of many natural and local advantages, Ireland is still behind not only the sister country, but even certain states which we have hitherto been accustomed to depreciate, such for instance as Spain, where, notwithstanding, we find that at the present time there are not less (completed or open) than 60 (exclusive of branch) lines of railway, com-

prising upwards of 4,000 miles in length, executed at a cost of about £61,000,000. And the intersection of the Russian interior, by main and branch lines of railway, is rapidly advancing; about 6,000 miles having been already opened, with 15 additional lines (comprising some 13,000 miles) in progress or commencing; while we will not greatly exaggerate, in describing the western margin of this country, from north to south, as almost inaccessible by railway.

The eastern and midland districts, at the same time, are comparatively devoid of branch or intermediate lines for internal communication, and this (apparently constitutional) paralysis seems to pervade our arrangements generally, as may be further inferred from the late failure of a very moderate proposal in connexion with a central metropolitan terminus before alluded to, together with the abandonment of numerous schemes of improvement, rarely matured beyond the stage of castle-building, or that of mere suggestion.

Abortive sanitary projects, and designs for main sewers, or for scouring the River Liffey, with competing proposals for the relief of Carlisle-bridge,* or, for the accommodation of vessels of larger tonnage, by increased depth of water, or additional harbours, are all instances which seem further to indicate an inherent infirmity of purpose; for, if it should be

* A revival of this project, as well as the proposed improvement in front of Trinity College, are again under Municipal consideration, and I trust we may now hope for their completion; though the former may still prove a failure, owing to the difficulty of deciding the claims of rival pretensions, the preservation of the existing bridge by enlargement being contemplated by some, while other competitors advocate the erection of an entirely new iron or stone structure.

The proposals to improve London-bridge by the attachment of lateral footways, whether by Mr. Fulton's cantilever plan, or by a compound system, with caisson, pier, and girder, to mask the present masonry work, on both sides, with iron, at an expense, respectively, of £20,000 or £80,000, will, from their heterogeneous character, scarcely be considered acceptable, as the load by increased traffic, together with the imposed side-weights, amounting to 700 or 800 tons, would render the question of further, and, perhaps unequal settlement of the combined work, a matter of uncertainty.

urged, as an extenuating circumstance, that this languid system is perhaps sufficient for our own moderate national requirements, it must still be borne in mind that commercial conditions keep pace by mutual reaction with internal improvements and facilities of transit.

Though numerous public objects in the interior of the country, such as the construction of bridges and roads, the erection of county buildings, or the carrying out of drainages, reclamations, &c., might be effected by the Government, or by the County Surveyor System of Ireland, the resources and initiatory efforts of the former can never be, as a matter of course, more than subsidiary, while the projects of the latter must be continually subject to the limitations imposed by the uncertainty of County Presentments.

I may now refer to one of the most extensive undertakings of modern engineering, which is afforded by the successful issue, or, perhaps, more properly, the restoration of the Suez Maritime Canal 99 miles long, in the month of November last; and, as a subject with which we are all equally familiar, I may observe, that the difficulties to be encountered in the first instance had reference (in my opinion almost wholly) to the means and instrumentality to be employed, and the chief commendation remaining to M. de Lesseps, as the engineer, is derived from his selection of the route, and the patient perseverance exercised in the completion of such an undertaking, under adverse local circumstances, and the unfavourable opinions formed by some of the most eminent authorities, which we are, as yet, hardly in a position to criticise or controvert.

No doubt much labour is still required to provide for the ease and security of the passage in the case of the larger description of vessels, and considerable annual expense, for the increase and maintenance of the depth and sides of the canal, can probably never be dispensed with, even supposing the additional aid of force and supply from impounding reser-

voirs; but I am happy to find at least the present success of the project somewhat assured (notwithstanding the adverse views* of such engineers as Messrs. Stephenson and Talabot), from the statements lately made by Messrs. Fowler, Bateman, and Hawkshaw, whose opinions are so justly entitled to respect.

The undertaking, in an engineering point of view, did not involve any hydraulic difficulties of a complex character requiring varied specialities of construction, the impediment offered at the commencement by the yielding slob being overcome, for, there being at either extremity of the channel but slight tidal force, with only a few inches difference of sea-level, navigable lakes, or depressions in the interior, affording, for the most part, further facilities, no provision, beyond some blasting of gypsum, sandstone, or conglomerate rocks, and sufficient excavation, became necessary to admit of the easy inlet and quiet flow of the water throughout the comparatively level deposit of recent or tertiary drift, and this was mainly effected (under the assistant engineers from the Polytechnic School) by the "drague," or steam-dredging machine, spade or hand-labour having been much dispensed with.

If then the outlet at Port Saïd can be sufficiently protected

* In adopting moderate opinions in connexion with this subject, from an engineering point of view, I am happy to find they receive more than support in Dr. Haughton's late paper, read before the Geological Society, an abstract of which I have received in time for reference, whence it appears that the learned professor forms very unfavourable anticipations, on geological grounds, relative to the durability of the canal, which he considers but the repetition of a project which has already proved a failure, the very existence of the Isthmus of Suez itself being due to the deposition of a natural bar by opposing currents, and sand drifts, which are still effective for its restoration, or the creation of a new one.

I can only say, that should we still maintain more cheering prospects, the misgivings of so competent an authority on physical geology are calculated to inspire a certain amount of apprehension, and the conclusions of the report completed by Colonel Clarke and Captain Richards are not highly coloured.

by the long concrete breakwaters, so that, after improving the curves, planting the new made banks, and stone pitching the slopes, the channel can, without immoderate expense, be kept clear of barring by the annual silting in of upwards of 8,000,000 cubic feet of sand for seventeen miles, with an opposite current from the south, the efficiency of the canal, as a maritime waterway, may be considered secure, supposing the general maintenance of sufficient depth, and we may further hope it will prove a financial success, at least for some time to come.

To obviate any difficulties of a hydraulic character which might have arisen, on the head of waste by evaporation, as affecting the permanent flow and volume of water in the canal, the means of its replacement, if necessary, became a preliminary consideration, for, judging from the fact that no less than between nine and ten millions cubic yards of water is daily evaporated from only one of the interior lakes, to a uniform depth of more than half an inch over a surface of about 155 square miles, it is apparent that the amount of loss, on this account, from large areas of water lying exposed at either extremity of the canal to the intense heat of the sun, as well as to the Continental winds blowing across the arid deserts adjacent, must, in proportion, be so considerable as to have originally induced some forethought on the part of the Hydraulic Engineer.

On examination, however, it was found that, in addition to a greater tidal rise of four feet, the mean level of the Red Sea was also slightly higher than that of the Mediterranean, or sufficient (from the evaporation being unequal in *amount*, though *proportionally* greater) to afford an opposing current, from the Suez side, of three miles an hour, with a diminishing velocity, at the Port Saïd extremity, of about one-half, so that, notwithstanding increased exposure to loss, the narrower sea is less the subject of the *actual* waste,

which reduces the Mediterranean over a much wider area to a lower level, and even below that of the surrounding seas.

The whole subject of inland or ship canals has of late attracted increased attention, either as suitable adjuncts for the transport of certain commodities in the interior, or as subsidies to maritime or overland routes, and this tendency may be observed from the intimations made, from time to time, in reference to designs similar to that of M. de Lesseps, as, for instance, in the case of the Isthmus of Darien, in South America, where, it is interesting to remark, in passing, that, as ascertained by the Panama Engineers, the currents, mean levels, and tides of the containing oceans present hydraulic conditions, wholly dissimilar from those of the Red and Mediterranean Seas—but, I think it premature to speculate, in the present state of the proposal, respecting the suitability of the inland mountain barrier of the Isthmus, as a matrix for a maritime canal.

In Ireland we find a revival of some of the abandoned questions of inland navigation, such as the Ulster Canal, and, indeed, it is gratifying to observe a reaction, from almost a state of collapse, in the improvement of the traffic and dividends in connexion with the Grand and Royal Canals, though limited to such rough cargoes as timber, slates, bricks, coal, peat, limestone, manure, grain, &c., &c., from which it is to be hoped that this species of communication may again prove sufficiently profitable to command a share of public favour, especially as its present adoption by the firm of Guinness and Co., indicates the limited practicability of floating small steam vessels in certain cases.

Notwithstanding the failure, from whatever cause, attending the attempt made to establish an American Packet Station in Galway, I think it may be safely assumed with Mr. Philips, that a still more extensive and profitable trade than that originally anticipated or at present realized, would

have resulted, had the route and dimensions of such a midland water-passage as the Grand Canal been designed, with more ambitious views, as well as with less divided counsels, under competent engineers, at least, if we are permitted to argue from the complex and expensive Dutch Canal now proceeding on a great scale, under Mr. Hawkshaw's directions, the construction of which has become indispensable, from the necessities of an increasing commerce having outgrown the means of transit hitherto in existence.

Though prematurely opened, the practical completion of the railway from New York to San Francisco, over the Rocky Mountains, in the United States of America, directly connecting the shores of the Atlantic and Pacific Oceans, affords a further instance of the success of designs, which, from their magnitude,* would formerly have been dismissed as chimerical, so that at present few proposals, within the limits of possibility, are regarded as impracticable.

Frequent mention is, from time to time, being made of enterprises of a like kind, and in many cases companies have been formed for their promotion, as may be observed in the various proposals for the extension of telegraphic communication, encouraged, no doubt, by the almost unexpected success of the great Atlantic cables, and the facilities offered by the Great Eastern Steam Ship, so that at no very distant period we may look for the establishment of easy relations with, not only remote places in foreign countries, which have hitherto been scarcely regarded as worthy of attention, but with the most distant points of our own colonial empire, to which, in

* A similar conception is afforded by the expected dimensions of the proposed Hudson River Suspension Bridge, near New York, to command a clear span of 1,600 feet, at an elevation of 155 feet above high-water mark, suspending a total weight of nearly 10,000 tons, and estimated to bear six times the weight ever imposed. The cables, of 14 inches diameter, are expected to comprise about 70,000 miles of steel wire, the approaches and towers consisting of, say, 50,000 square yards of solid masonry.

addition, overland approach by railway is extending; and the Mont-Cenis Tunnel, in effecting a junction between the lines on either flank of the Alps, will further an advance eastward, from which ulterior advantages of an important character may be expected, even supposing General Chesney's Euphrates expedition design to have been a mere Utopian conception.

It should not be forgotten, however, that notwithstanding the possession of a monopoly, the expense which will have ultimately been incurred for the excavation and construction of this remarkable pass, previous to its being in operation, precludes the hope of such a speedy return as might be desired to reward the patience of the promoters, so unusually taxed by the delay arising from the removal of the indurated crystalline strata of the mountain, probably in the line of strike, which, from their geological identity, I would suppose presented difficulties to the engineer, similar to those encountered by Mr. Greene at Roundwood with such adverse results, notwithstanding the difference between the muscle of the British, as compared with that of the Continental navvy.

In this view also we hear of schemes for more speedily reaching the coast of France than by the sea passage hitherto available, such as (Mr. Fowler's), by the transfer of entire passenger trains and loaded trucks from the terminus of one to that of the other shore, between decks of a kind of wave-proof ferry* or movable bridge; or, again, by the extension of Mr. Barlow's principle of subway, by cast-iron tubing and pneumatic propulsion beneath or upon the bed of the channel, and even the carriage of a line over a bridged way supported by turrets, or, as it were, stationary trestles has been suggested.

* This proposal has since received the sanction of Parliament, and it will, of course, involve considerable expense to provide the steam vessels for the service (450′ × 57′), to run 25 miles an hour, with the hydraulic lifts, and suitable harbours at Dover and Andrecelles.

We have heard of M. Boutet's model bridge or passarelle, of a single span of 100 metres capable of resisting deflection, but I am not sufficiently acquainted with the details of the proposal to discuss its principle; though I may observe, that the main, if not only, impediment to the success of unprecedented designs, if at all practicable, will be confined to difficulties arising on the head of excessive expense, as in the case of one of the schemes before mentioned (that of the turreted or trestled line), the estimated cost of which amounts to a sum of £30,000,000 sterling; but, supposing the realization of any of the foregoing plans, it will not over-tax our imagination to foresee the ultimate junction of the northern shore of Ireland with the opposite coast, either at Portpatrick or the Mull of Kintyre.

We have already been led to consider something like an analogy suggested by Mr. Hodgson's Endless Rope system in the instance referred to by Mr. Cotton, the spread of the idea affording the best indication of its value; and it would be difficult at present to say, what variety of useful combinations it may not yet present in connexion with further appliances for the improvement of a comparatively speedy and inexpensive means of transit or locomotion, especially under peculiarities of condition almost limited to its application.

In contemplating the territorial extent of our Colonial dominions as a field of enterprize, some disappointment is felt at the disproportion existing between the necessities of so wide a sphere of action, and the engineering projects actually in progress, and, from the *prestige* of the country, this unexpected inequality hitherto appears, I regret to say, in a more striking manner with respect to our Indian empire, than in connexion with dependencies of less promise or resource; while from whatever point of view we seek to discover a satisfactory solution of the problem, difficulties of a peculiar character are presented.

I could hardly offer a decided opinion as to the correctness of the causes, whether administrative, social, or professional, which have been assigned for this comparative inaction; but if it be true, as I have heard alleged, that a professional jealousy or rivalry arising from a sort of *esprit de corps* feeling exists in that country between the *Military* and *Civil* Engineers, as such, I think it is much to be regretted, as indicating an unhealthy condition from which nothing can result but disastrous consequences; we may, however, hope that good sense will prevail to effect the discontinuance of invidious distinctions, which only tend to the promotion of frivolous party interests.

The foregoing observations, of course, chiefly refer to our desire for the removal of every element retarding the full restoration of professional prosperity, as, otherwise, Indian affairs are beginning to afford rather subject of congratulation, considering the progress of reaction from the effects of such an unexampled war as that of the great Sepoy Revolt of 1857, with the political results arising from the cession of the Company's Charter, and we have no reason to anticipate any retrograde movement in this respect under the auspices of Lord Mayo,* the present Governor-General, who has so

* I have received an interesting account of the ceremonial opening of the Great Indian Peninsular Line of Railway, at Jubbulpore, by the Governor-General and H. R. H. the Duke of Edinburgh, where his Excellency made some observations, from which it appears that this great Peninsular Trunk Line, from Calcutta to Bombay, is 1,300 miles in length, a paid-up capital of £22,000,000 having been already expended by the Guaranteed Company; but that in the year 1868, when there were 4,000 miles of railway between Madras, Bombay, and Calcutta, nearly complete, at a cost of about £85,000,000, it was thought desirable to change the system of extension in future, by the exercise of direct Government control, with a view to an auxiliary scheme, embracing full 15,000 miles of interior branch lines of railway, about 6,000 of which are either open, in progress, or commencing, while the Guaranteed Companies may expect a share of 2,000 miles additional, which are at present being projected.

Lord Mayo further alludes to the discovery of coal fields as one of the principal

promptly recognized the growing importance of developing the internal resources of the country, by the encouragement of every kind of enterprise at the present juncture, when the opening of the passage by Suez, and the great arterial lines of railway between Calcutta, Bombay, and Madras,* will suddenly advance commercial intercommunication towards our shores by a decreased distance of some 10 or 11,000 miles, besides the overland postal and telegraph services, which already effect close intercourse.

It thus appears that the dawn of a new era has arisen on a sphere of action sufficiently extensive to satisfy the most sanguine aspirations, and improvements of a marked character may henceforward be expected to pervade every department of Indian enterprise, especially in developing its vast commercial, agricultural, and probably mineral resources, by the introduction of the most effective means of establishing comprehensive systems of irrigation and drainage, as well as inland (river or canal) navigation and public roads, to open hitherto almost inaccessible regions, by which malarious districts of swamp or jungle will be replaced by prosperous

subsidiary objects to be secured, and, in stimulating such researches, he refers to their success in the Chanda, Wurdah, Nerbudda, and other coal districts. He also hopes for the discovery of further supplies of mineral fuel, from petroleum being suspected to occur in the Punjab.

Reference is also made to the services of Mr. Brereton, the Principal Engineer of this great Peninsular Line of Railway, the difficulties of which are described as having been chiefly encountered in crossing the Bhore and Thull Ghaut inclines, which alone cost £2,000,000, as also in passing the sickly jungles of Nimara, and the Nerbudda Valley. Special mention is made of the Towah Viaduct, constructed by Mr. Rushton, as the finest instance of masonry work on the whole line; and, in connexion with the East Indian Railway, Messrs. Berkeley and Turnbull are deservedly complimented.

* I would have wished, had it been read in time, to refer to some of the leading details of the "Description of Pennair Bridge," lately given by one of our members, Mr. Edward W. Stoney, Resident Engineer, Madras Railway, but it can already be referred to in the Proceedings of the Institution of Civil Engineers, London.

towns or villages, or by productive lands, suitable for either tillage or pasture.

An advance has already been made in this direction, as in the case of the Damoodah Canal, 100 miles in length, lately sanctioned, which it is thought may be completed at an expense of about half a million, when, in addition to the main commercial object, the indirect effects expected from the drainage of a wide area, hitherto wholly devoted to malaria and fever, will be satisfactorily ascertained; but in any case the supply of Bengal coal at a cheaper rate than by railway to Calcutta, may be regarded as an important advantage.

The establishment of ports and harbours likewise, for the advancement and accommodation of the coasting trade, by the selection of suitable sites, has not been overlooked by his Excellency Lord Mayo, and I believe a competent Engineer is about to be, if not already, appointed for that purpose.

These are the main features relating to the present state of Engineering in India, but the reclamation of lands now waste, or the erection of new buildings, suggests a few reflections in connexion with the surveys on which valuations for assessment, or other Government or scientific purposes would be based.

Besides the geological survey, under Dr. Oldham, now in an advanced state, Colonel Meadows Taylor makes us acquainted with native surveys of village lands, and, in pursuance of the subject, he could, no doubt, supply further desirable information with respect to such topographical maps as are at present in use.

Meantime it may be interesting to offer the substance of some information which I formerly received from Mr. H. Newill, Director of the "General Survey and Settlement of Land Revenue" for the Madras Presidency, relative to the system most conducive to the successful conduct of a Government Valuation in India, for purposes of assessment, with

the maps and scales most suitable to be adopted for that object.

Besides a trigonometrical survey, it appears there are tenement, or village and field surveys effected in districts of 100 square miles by the "traverse system," from which maps are constructed containing boundaries, field contents, and topographical features in detail; and hills, village sites, tanks, channels, roads, groves, &c., with the various kinds of tenure, and lands, whether irrigated, cultivated, waste, or unproductive, as the case may be, are all appropriately distinguished.

The maps are of various kinds, and on different scales, according to the purpose for which each is designed; thus some comprise districts of 5 or 6,000 square miles laid down to a scale of half an inch to a mile, while what are called "Talook" maps, for administrative purposes, are prepared in subdivisions varying from two to six hundred square miles, on a scale of two inches to the mile, the maps of the village lands of the Carnatic being at the same time constructed on a scale amounting to as much as sixteen inches.

In a paper which I read before the Institution in the year 1859,* on the scale to be preferred in maps for National or Governmental purposes, I offered a decided opinion in favour of a scale of 25 inches to a statute mile, as being the $\frac{1}{2500}$ aliquot part of the linear measure of the ground itself, and this opinion was supported by Sir Henry James, and the Report of the Royal Commission, in the case of cultivated districts, as involving little more expense than that required to complete a survey on the 6-inch scale at present in use, while no comparison could be made with respect to the increased range of purposes which the adoption of the larger scale would subserve.

In a sketch of the system pursued in the conduct of the General Survey and Valuation of Ireland, prepared in conjunction with Sir Richard Griffith, in answer to

* *Transactions of the Institution of Civil Engineers of Ireland*, Vol. v., p. 192.

inquiries made on the part of the Madras Government, I even pointed to the advantage of adopting a still larger scale, or one of 5 feet to a mile, in the case of towns, villages, and close or highly cultivated districts, from which no difficulty would be experienced in laying down on the map, and accurately computing the areas of tenements, not exceeding, even, a rood in extent; and I therefore cannot approve of the scales before referred to as employed for the "*District*," "*Talook*," or *Carnatic* and *Village* maps of the Indian surveys, which I am of opinion are too small to subserve purposes for assessment, however suitable for geographical, travelling, or military objects.

I do not, at present, propose to offer an opinion in reference to the abstract principles upon which a National or General Valuation should be based, but I may state that the process to be carried out by the Irish Valuation department, in ascertaining the fair letting or productive value of rateable property, as from time to time adjusted by annual revision, embraces the due exercise of every subsidiary or suitable means of securing so desirable an object.

With this view, ample provision for the guidance and uniform action of the several persons employed, is given in the form of "*Instructions*," comprising detailed suggestions relative to every description of assessable or exempt tenure, with scales, tables, and formulas relative to machinery, average produce, market, and acreage prices, local circumstances, building measurements, and rents, together with the mode of valuing railways, works, factories, quarries, mines, &c., and the technical nomenclature, and classification of sub, or active soils, according to their mineral composition, physical character, or powers of production; and the importance of this last element is specially referred to in Mr. Newill's memorandum (No. 296), as an indispensable requisite in the conduct of a scientific valuation, such Indian terms as "regur, or black cotton, or red soil," from their limited signification, being

insufficient for the requirements of a systematic and descriptive classification, necessary to exhibit the distinctive qualities of the numerous varieties of soil of which arable, pasture, or moor lands are composed.

Notwithstanding that occasional improvements or projects in the shape of railways, tramways, waterworks, telegraphs, docks, light-houses, &c., might be alluded to* elsewhere, as in South America, Vienna, France, Malta, Liverpool, Oban, or otherwise, our remaining attention may, perhaps, be profitably limited to London, where Metropolitan enterprise is exhibited in such a degree of activity as to preclude any attempt at comparison with that of other localities, the various undertakings of which being, it may almost be said, there centralized.

However the variety, and diversity of construction of the several objects of Engineering interest in London are to be regarded, their systematic connexion, as portions of a main design, is apparent, having been all undertaken with the object of providing the greatest amount of facility for the ever-growing traffic of the Metropolis on the one hand, and of improving its municipal or sanitary arrangements on the other, in either of which points of view their special suitability may be separately considered, without further regard to any definite order.

The New York system of Tramways, already working so satisfactorily in such cities as Liverpool or Vienna, with the line from Kennington to Brixton nearly complete, is about to be generally extended, and their introduction into Dublin is much to be desired, as the commencement of further undertakings; but, wherever adopted, their beneficial influence on city or suburban passenger traffic admits of but one opinion, the only question still under discussion being the relative

* Though not beyond our province, I omit any reference to the progress of naval or military engineering, our attention being less frequently drawn in that direction.

advantages to result from their lateral or central position, the former of which I myself prefer, both as the practice hitherto in existence, and after due consideration of every argument which has been advanced on either side of the question.

For the relief of the increasing overground traffic, the question of tunnels, sub, and covered ways (or understream bridges), as connecting the inner and outer circular railway systems, comes appropriately before us; though with regard to the last, from their similarity, little further need be said, owing to the description of the Metropolitan and St. John's Wood Railway, already given in Mr. Crosthwait's paper; and the East London Railway, as a portion of the outer circle, extending, under Mr. Hawkshaw, assisted by Mr. Burleigh, to Wapping and the Broad-street Station, to join the North London Line, is chiefly remarkable for its passage through the Old Thames Tunnel only four feet beneath the bed of the river, the suitability of which, in this respect, affords subject of congratulation, in effecting the escape of so interesting a souvenir from oblivion.

The contrast, however, both as regards the time and expense of its construction, is striking, as compared with Mr. Barlow's elegant, as well as simple, cast-iron tubular subway, which, being completed in a period of nine months, for a distance of upwards of 1,300 feet, at a cost of about £16,000, so far surpasses, in ultimate utility, a structure requiring twelve years for its completion, at an amount of £450,000; though we are fortunate in retaining the associations, as well as the use of an enduring monument to the memory of Sir M. Isambard Brunel.

It would be out of place to repeat a description, already so well known, of the simplicity of the process by which the segment fittings in the excavation for the seven feet tube were steadily advanced by Mr. Greathead the Contractor, at the rate of nine feet a day, between the circular lift-shafts of Tower Hill and Tooley-street, at a distance of from twenty to

thirty feet, beneath the bed of the Thames, through the dry London clay, which, (in addition to the protection afforded by, as it were, grouting the space surrounding the tube with a ring or coat of blue lias cement), is so well adapted for the exclusion of injurious moisture; but another subway, with double passage, being proposed between Southwark and the city, it is gratifying to record the success of the first experiment in this mode of transit, as an expeditious movement acting by its own momentum, on a tramway of 2′ 6″ gauge at a given incline, which in this instance is as steep as 1 in 40.

It is only an appropriate tribute to recall the memory of Mr. Barlow's father, the distinguished Engineer of the Lambeth Suspension (or overstream) Bridge, who originated the design of *underbridging* the river, which we have now to acknowledge, as so skilfully effected, and with such promise of return, by his son.

It has given rise to some disappointment, that no object of geological interest, organic or mineral, should have occurred in the London clay, excavated on such a scale, vertically as well as horizontally; but (though perhaps not an equivalent find) it is interesting to remark the discovery of a wide and well paved road, with some silver coinage of the reigns of Henry III. of England, and Alexander III. of Scotland, in sinking the entrance, or lift-shaft, to a depth of sixty feet beneath Tower Hill, and these objects were certainly of a more desirable kind than the ghastly relics disclosed by the Holborn preparations at St. Andrew's Church Yard or Hatton Garden.

Though not exactly subways of like construction, or for the same purposes, I cannot avoid expressing a wish for the extension of such underground passages as would concentrate what might be termed the conduit, or tubing systems of large towns, similar to that already so massively constructed beside the Holborn Viaduct, by which every description of municipal pipe, including telegraph wires, and perhaps occasionally

pneumatic postal tubes, would be contained in only one course, so as to obviate the present expensive, as well as irksome blockade, and subsequent restoration of the crowded thoroughfares, which would likewise be much relieved by the excavation of sub-crossings, as proposed in Paris, to serve also as easy adits to some of the conduit vaults.

From long residence and continued intercourse, I almost take the interest of a citizen in London projects and improvements, but while gratified at the early completion of the comprehensive main drainage scheme of the Metropolitan Board of Works, as an indispensable sanitary measure, I regret being at the same time obliged to withhold approval, as regards the present arrangements for objects of equal, if not greater importance, respecting the supply and quality of the water; but the proposal for the introduction of a supply from the Lakes situate in the primary district of Cumberland, at a cost of over £20,000,000, has probably been hitherto considered too expensive for adoption; though the water of the upper formations must always be expected to hold in solution the impurities of their mineral constituents, which are often highly calcareous or chalybeate.

Upon the completion (by Mr. Fowler) of the Metropolitan District Line, partly a girder covered way, to the Mansion House and Canon-street, the Great Thames Embankment (100 feet wide), with its portion of the main sewerage, subways, approaches, and landing stations, so rapidly advancing under Mr. Bazalgette, will effect an important change, by joining the centre of the city to Westminster and Kensington, from which a considerable modification of the existing western and central commerce and intercourse may be expected, as a natural result of the creation of new facilities of transit, a re-arrangement of a marked character becoming more probable by the construction of the Holborn Viaduct and Blackfriars' Bridge.

Many of us were, no doubt, present at the late ceremonial opening of both these structures, which so well deserved the

inauguration of a royal and municipal pageant; and original designs of such magnitude and engineering skill afford lasting memorials of the professional achievements of Messrs. Cubitt and Haywood, besides reflecting credit on Mr. Bryant, Messrs. Thorne, the contractors, and all the parties concerned in carrying out undertakings of national, rather than local, interest.

Without prejudice to the controversy respecting the relative advantages and economy of masonry, as compared with iron, in the construction of bridges, the erection of the new Blackfriars' Bridge, about 1,270 feet long by 75 wide, in wrought-iron plate-girder work, is an improvement of which no doubt can be entertained; as, in addition to its greater width of road and footways, by about 32 feet, the clear headways for the river traffic beneath, varying from 25′ to 17′, though slightly less than the average of those of the former decayed stone structure, are in reality of a more effective kind, from the facilities afforded for more equal distribution, through a navigable road enlarged 57 feet, by retaining the use of the whole of the five flattened segmental arches of the recent structure, the two outer of the nine elliptical arches of Mylne's Bridge having been scarcely of any available service.

Irrespective of the general ornamental character, in the Venetian-Gothic style, of the bridge and balustrades, as a civic monument, its comparatively horizontal gradients of 1 in 40, replacing the former declivities of 1 in 24, entitle it to preference; but the width of the spans exhibits its marked superiority, as they generally exceed those of most arches of a similar kind, the centre reaching 185 feet, while the land spans are 155, those of the intermediate arches being 175 feet; and the waterway is further increased by the reduction from eight to four in the number of the piers, which are built of Cornish granite from the De Lauk quarries, and centred with brickwork laid in cement.

An exceptional feature in the construction of Blackfriars' Bridge is the security of the foundations laid for the piers,

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Unlike the late Mr. Pearson's proposal to raise the valley by 15 feet, the principle of Mr. Haywood's design is characterized by great simplicity, and may be described to be the successful creation of an almost straight and level viaduct, 1,400 feet long by 80 feet wide, with roadway and side paths sufficiently inclined for drainage (50′ × 15′), from Newgate, by Skinner-street, to Hatton Garden, on what might be termed *a tubular principle of cancellated or cellular structure;* as the medium of support consists of a mere triple, or compound congeries of continuous vaults or cellars, securely rooted in the London clay, the central roadway resting on a series of double arches (24′ span), with lofty tiers or storeys of transversely divided vaulting (10′ span), which, from a concrete foundation, rise like terraces to the required height on either side of the roadway, serving to sustain the footpaths, and, with the larger cellars, to afford, in addition, accommodation for the storage of goods, the principle thus developed containing a germ of wider application.

The bridges in connexion with the viaduct admit of little further remark, as the description of that across Farringdon-street, which forms the ornamental feature of the undertaking, has in some measure been anticipated in considering the more extensive Blackfriars' structure, the difference being mainly due to change of situation, which rendered it necessary to adopt the oblique principle (diagonal angle about 55°) for a cast-iron coupled girder skew bridge, 117 feet long by 80 wide, consisting of a 66 feet central, and two narrow lateral spans.

The masonry, and iron-work* for the balustrades, spandrels, &c., as for Blackfriars' Bridge, are of an elaborate character, and several varieties of granite (Isle of Mull, Aberdeen, Guernsey, or Devon), and Portland stone are used for the twelve supporting columns and solid abutments, the foundations of which

* The castings, and iron-work generally, were completed by the firm of Cochrane, Grove, and Co., the East Indian railway contractors.

required to be sunk into the London clay, fully 30 feet through the treacherous deposits of the spongy Bourne, and Fleet River bottoms, which were found to contain the remains of old struts, timbers, piles, and abutment walls of, probably, the former bridge or wharves.

It would be difficult to form a decided opinion relative to the fissures and cracks running irregularly in six of the red granite supporting columns (each five feet in diameter), as we are not acquainted with their extent, or whether, for the most part, they may not be only superficial, and, as the report of a competent Commission (including Mr. Bidder) is contingent on their condition, after the lapse of a sufficient length of time for final settlement, it would hardly be desirable to anticipate the probable result of a pending inquiry.

The corner buildings, consisting of upper and lower chambers or offices, erected to contain public staircases 11 feet wide, independent of the rich bronze casting, carving, and statuary work (by Messrs. Bursill, Farmer, and Brindley), form, with their balconies and caryatides, an imposing feature of the Farringdon-street Bridge; and the remaining bridges in connexion with the viaduct are in sufficient keeping with the general character of the design, the Shoe-lane oblique wrought-iron girder structure, and that of the Chatham and Dover Railway, having each highly finished parapets; and the latter is accompanied by subways, as at the sides of the viaduct arches, for sewage, &c., from which they differ in being constructed of wrought-iron, the vaults in the former instance (about 12′ × 7′) consisting of arches, often so exceptionally strong as, instead of the ordinary five, to contain fully eight rings of brickwork.

Relying on your partiality, I have probably trespassed in extending the foregoing observations; but, as my opportunities of contributing to our proceedings are necessarily circumscribed, in consequence of the pressure of the public service, I felt it incumbent to embrace the present occasion in an

endeavour to justify your choice of a President, and I hope I can reckon on your kind acceptance of the attempt.

I may express, in conclusion, a wish for the future development of Irish resource—especially as, with that view, some years ago, I supplied Mr. Hunt, of the Mining Record Office (Jermyn-street), with as accurate an account and catalogue of rateable and open quarries as could be prepared from the documents of the Irish Valuation Department; and if the supplies required throughout the empire from such sources be taken into consideration, I am of opinion that our quarries have not hitherto received the amount of attention to which they are entitled.

The variety and quantity of quarry materials in demand, can be easily estimated from the contracts for such undertakings as the Thames Embankments, or those of Dagenham, or Poplar; the East and West India Dock Extension of the latter (with its locks, gates, jetties, quays, warehouses, and water area of 33 acres), being executed by Mr. Hawkshaw, on so enlarged a scale as to require the construction of a railway to connect the Docks with the London and Blackwall Line.

In a rapid survey of the Map of Ireland may be observed the areas occupied by varieties of granite* of superior quality, such as those disclosed on the western coast of Donegal, at

* Mr. Harte, the County Surveyor of Donegal, has opened a valuable quarry of red granite at Sheskinarone, near the western coast at Burton Port, which successfully competes with the best specimens of the Scotch markets; and the superior quality of the slates supplied by the Killaloe quarries, at Douharra, with those so actively worked in the neighbourhood of Derry Castle, at Loughtea, and Tomlough on the Shannon, inspire confidence respecting the extensive schistose districts still undeveloped in Waterford, Wicklow, &c.

The Duke of Devonshire's Castle at Lismore affords a striking instance of the durable and ornamental character of the Southern Yellow Sandstone; and the value of the several varieties of crystalline or earthy carboniferous limestone or shale from Limerick, Cork, Galway, Armagh, Westmeath, Kilkenny, Dublin, &c., is well exhibited in numerous designs and buildings throughout the country, as in the ancient Abbey of Askeaton, Mr. Pugin's Church at Dundalk, the Chapel Royal in Dublin, and other metropolitan structures.

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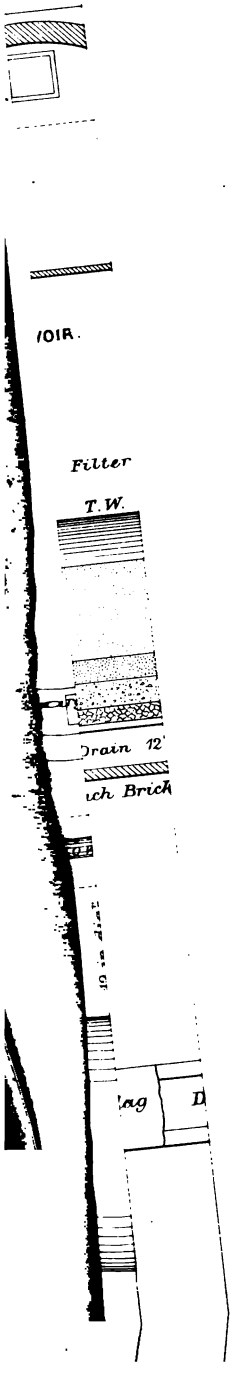

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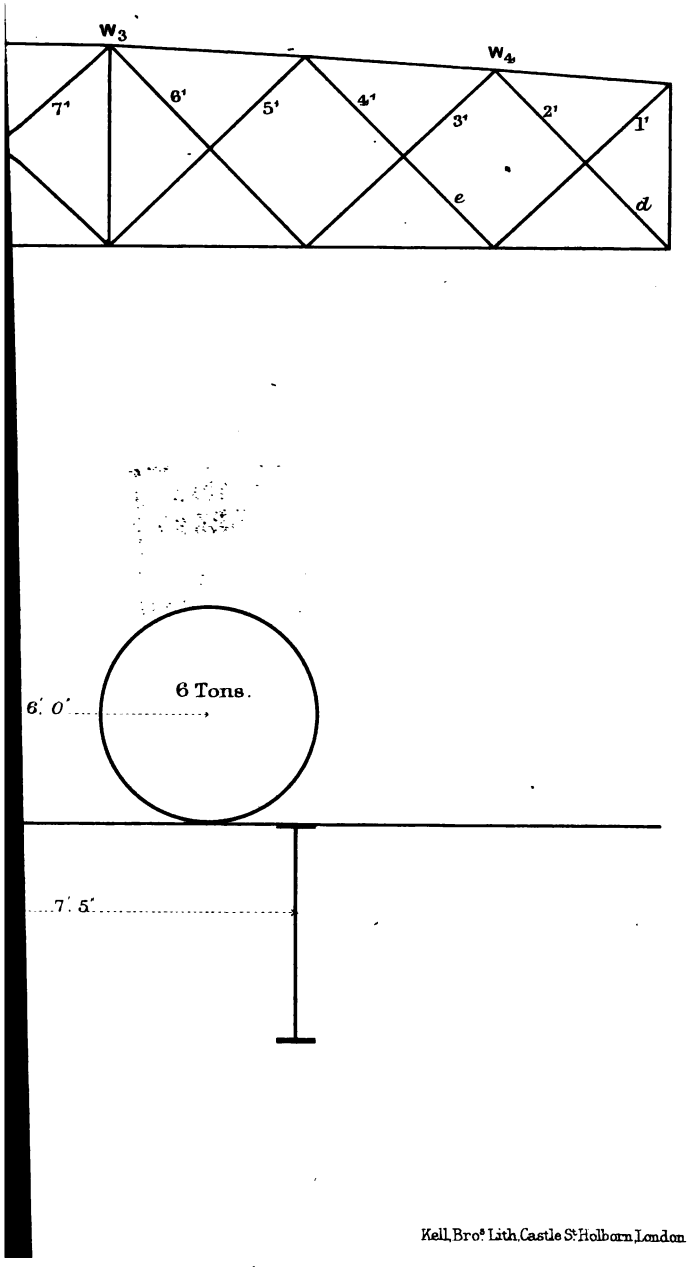

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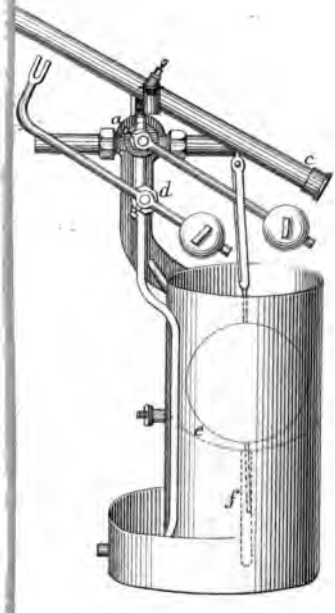

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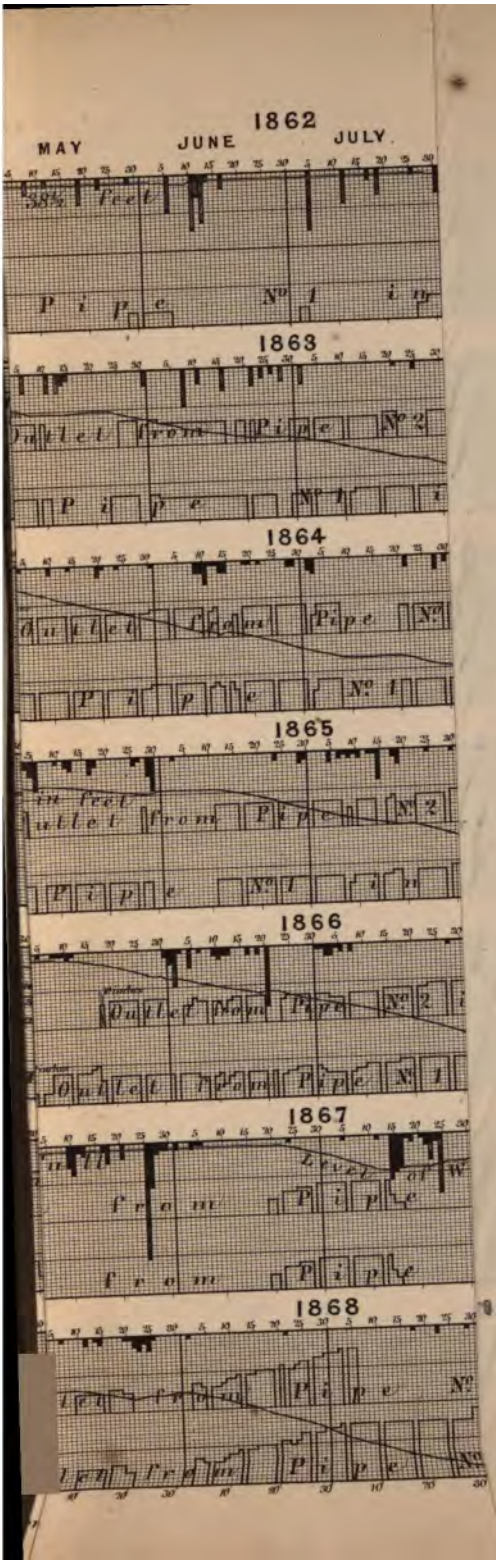
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POORLAND

Fig: 3.

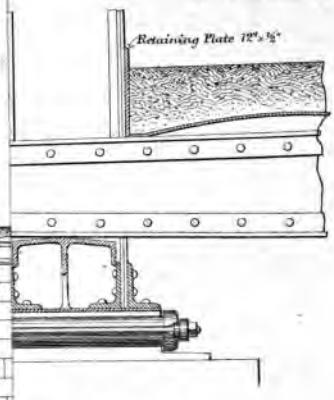
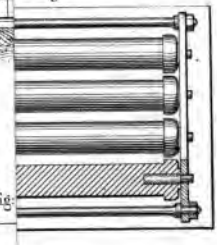


Fig: 6.



Scale for Fig.
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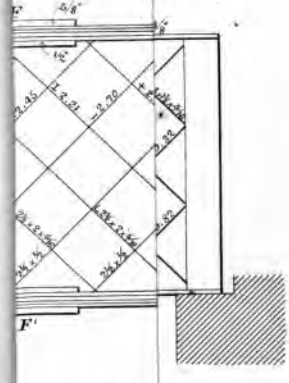

Fig: 8.

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Figs 8, 9 & 10.
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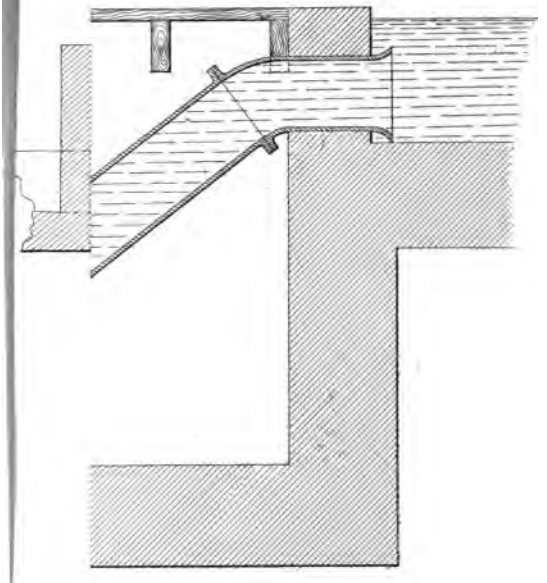

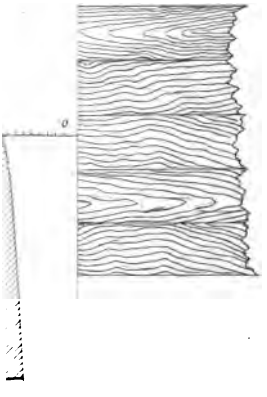

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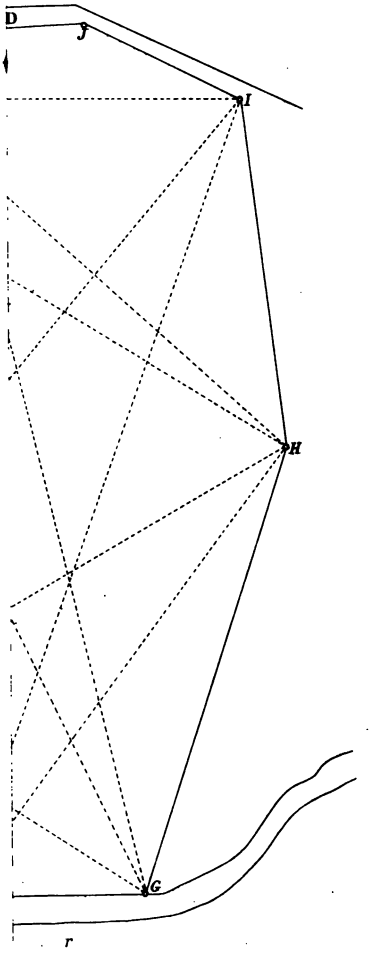

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